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CORRECTION

Monthly Weather Review, April, 1929, page 159:

In Figure 1 the *solid* line refers to *water;* the *dotted* line refers to *wind.*

MONTHLY WEATHER REVIEW

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PREDICTING MINIMUM TEMPERATURE, ESPECIALLY AS A FUNCTION OF PRECEDING TEMPERATURE

By Esek S. Nichols

[Weather Bureau office, San Jose, Calif., March 12, 1930]

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INTRODUCTION

The fact that the morning minimum temperature is a function of several variables, the effects of some of them obscure, is shown not only by theoretical considerations but also by the variety of methods that have been proposed for its prediction, as well as by the considerable scattering of dots above and below the lines of best fit on all minimum-temperature dot charts, even those prepared for restricted conditions.

PREDICTION FROM THE EVENING DEW POINT

Some early studies of minimum-temperature prediction used preceding dew point as a standard of reference; e. g., in 1910 O'Gara reported that in the Rogue River Valley of Oregon, under certain conditions "there is a relation existing between the dew-point temperature observed in the early evening and the minimum temperature of the following morning." (1). He stated equality of dew point and ensuing minimum under certain very restricted conditions; and mentioned other conditions that are followed by minima above or below the dew point, although he did not evaluate the effects of these latter conditions to any extent. The restrictions and modifications placed by O'Gara upon the use of the relation stated by him were necessitated by the fact that the dew point alone does not determine the ensuing minimum temperature. (See also (2), (2A), (3), and (4).)

Other contributions to the subject of direct dew point minimum-temperature relations are referred to by Ellison, who concludes that the dew-point formula is "inherently faulty." His conclusion depends on the inference that the formula in question is based on the easily-disproved principle that "the minimum temperature would not be lower than the temperature of the evening dew point" (5). However, this "principle"

differs widely from O'Gara's expression of a "relation" and from my consideration of the minimum temperature as a "possible function" of the dew point. (3) (p. 213). In fact, the hygrometric minimum-temperature formulas simply state that at a given relative humidity the ensuing minimum temperature is a function of the dew point; and thus these formulas are essentially modifications and extensions of the general dew point formula (12).

HYGROMETRIC FORMULAS AND GRAPHS

As has been stated many times, it is customary to derive a hygrometric formula or curve by finding the line of best fit to the employed data as plotted on cross-section paper, relative humidities as abscissas and departures of ensuing minimum temperature from preceding dew point as ordinates. In early investigations straight-line relations were stated; but this method was soon found to be inaccurate, and parabolic curves and equations were fitted to the dot charts (12).

Still later I found that the rectangular [1] hyperbola having asymptotes parallel to the axes of coordinates is in many cases preferable to the parabola, and subsequent experience has convinced me that it is generally preferable. However, if the original dot chart on which the curve of best fit has been drawn is used in actual forecasting, as suggested previously, it is unimportant whether the curve be of parabolic, hyperbolic, or other form, since results will be taken directly from the graph without computation. Therefore, a free-hand curve, its course guided by computations as described below, will often be most desirable (9).

METHOD OF ARBITRARY CORRECTIONS

Young employs as his basic formulas straight-line equations of the Donnel type, to which are applied series of corrections for groups of values of dew point and relative humidity separately. Ellison, in the paper already referred to, develops from data for Medford, Oreg., a set of straight-line formulas after the Donnel-Young method. In order to make these formulas fit the data more closely he applies a series of arbitrary corrections, according to Young. The formula (8) found for clear weather is,

$$y=d-\frac{h-20}{4}+V_d+V_h$$

d and h are evening dew point and relative humidity, respectively, y is the indicated minimum temperature, and V_d and V_h are corrections for groups of dew point and relative humidity values, as follows:[2]

d	V_d	h	V_h
°		*Per cent*	
7-24	+10	12-21	0
25-29	+3½	22-26	−½
30-35	+2	27-30	−1
36-43	−2	31-39	+1
....	....	40-51	−1

When E_d and E_h are each equal to O we have the base line of the formula, a straight line whose equation is

$$Y=y-d=-\frac{h-20}{4}=5-\frac{h}{4}.$$

This the lower straight line of Ellison's Figure 2, reproduced as the line AB of Figure 1, herewith. We may now represent the corrections E_h graphically by modifying the course of AB to form the irregular line Abc . . . . . B. We may then raise or lower this irregular line bodily through the number of spaces corresponding to each dew-point correction, V_d, and obtain the irregular lines $A_1 B_1$, $A_2 B_2$, $A_3 B_3$, $A_4 B_4$, which completely express Formula 8 for clear weather graphically. Similar sets of irregular lines would be obtained by plotting Ellison's formulas and corrections for partly cloudy and for cloudy weather.

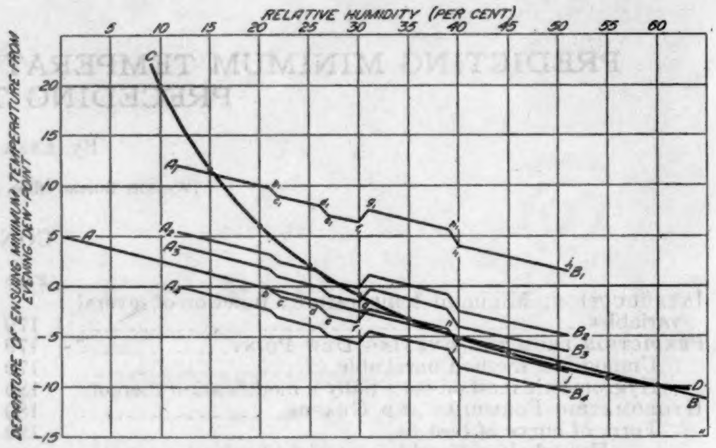


FIGURE 1.—Donnel-Young and hyperbolic curves from Medford data

Using Ellison's data for Medford, Oreg., plotted on his Figure 1, let us now determine a hyperbolic formula for that station. Pass a rectangular hyperbola through the points (10, 20), (30, − 1), and (60, − 10), which are taken as "star points" according to the method previously described (9). We obtain the equation $(X+10)\,(Y+22) = 840$, or

$$Y=\frac{840}{X+10}-22$$

which is the equation of a rectangular hyperbola having as asymptotes the lines $X=-10$ and $Y=-22$. The curve is drawn as the line CD on Figure 1.

Figure 1 serves at least two purposes. First, especially if we transfer lines AB and CD to Ellison's Figure 1, we may compare the parabola with the hyperbola and with the arbitrary-correction formula. Second, the reader may by actual trial determine for himself whether it is more convenient to obtain the indicated minimum temerature by substitution of proper values in a formula or, as I have suggested, to read the minimum-temperature departure directly from the graph of the formula as drawn on Figure 1.

We are unable to agree with Ellison in the claim that the arbitrary-correction method as described by him is more accurate than others. The parabola, hyperbola, or other form of curve should be considered as a basic or general curve. If at any station we find a consistent variation from the basic curve when used under certain values of dew point, for instance, we have only to draw other curves above or below the standard curve or to prepare another chart for use with such special dew-point values, as was exemplified for certain stations in Supplement 16 of MONTHLY WEATHER REVIEW.

Thus the curve CD occupies the same position in the hyperbolic system of curves for Medford as does the

[1] Not "rectilinear" as erroneously stated by Ellison in (5), p 490. The curve is the rectangular or equilateral hyperbola having asymptotes perpendicular to each other. [The word "rectangular" was misprinted "rectilinear".—Ed.]

[2] Temperatures in degrees Fahrenheit are used in this formula and others considered in the present paper.

irregular line Abc . . . . . B in the arbitrary-correction system. A comparison of these two lines with the data of Ellison's Figure 1 is not particularly creditable to the latter, which differs comparatively little from the Donnel straight line AB of our Figure 1. However, as a result of previous experience with data for other stations, it may be stated with confidence that the supplementary hyperbolic curves that would be obtained if dew points were available for each separate Medford observation used by Ellison, would differ much less from their basic curve than do the final arbitrary-correction curves from their basic line Abc . . . . B, thus the advantage found at first for the hyperbolic form, would be lost. Our special curves would or would not be parallel to each other and to the basic curve according to indications of the plotted data. If the data showed that supplementary curves would be useful, we should draw and use them; otherwise we should use the basic curve. We conclude, then, that the hyperbolic may be made equally as accurate as the arbitrary-correction method when properly applied.

Using the same Medford data as before, Ellison derives a "Nichols free-hand curve formula" and applies the method of arbitrary corrections thereto. For values of h he finds corresponding corrections V_h, but these "corrections" are evidently averages of ordinates of all plotted points having the abscissa h specified in each case. Thus he refers his curve to the X-axis instead of to the basic line AB, as in Young's method, and simplifies the formula by thus eliminating the expression $\frac{h-20}{4}$, or similar fraction. The corrections, V_d, given for groups of values of dew point, raise or lower the basic curve (of the Nichols free-hand formula) bodily, the same as in case of Ellisons formula 8; and thus produce a family of special curves parallel to each other and to the basic curve, which method is evidently inferior to that of drawing supplementary curves, already described, parallel to basic curve or not, according to data.

When h has the values 20, 21, 22, and 23, he obtains the following values for V_h; 4⅓, 3½, 4, and 3, respectively. When these data are plotted on cross-section paper, an S-shaped irregularity appears in the curve through the dots. He states that "the line of best fit is irregular," and that "the addition of the method of arbitrary corrections will produce the same irregular line of best fit to any hygrometric dot-chart" (see (5), p. 493), evidently meaning that the line of best fit is any line, regardless of form, that passes through or nearest to the greatest number of dots on the chart. However, the S-shaped irregularity referred to does not appear in plotted forms of Ellison's formulas 7 and 8; and the irregularities in the latter do not appear in the corrected Nichols free-hand curve, although derived from the same data, using the method of arbitrary corrections.

The fact that the basic line used by Ellison in obtaining V_h for the free-hand curve is the X axis, while he uses other straight lines in formulas 7 and 8, in itself makes no difference in the final curve obtained, as he very well indicates. Rather, he fails to obtain the same line of best fit because of different methods of handling the data. Thus, in the free-hand case V_h is determined for each per cent of relative humidity from 12 to 52; in other cases for groups of relative-humidity values. Also, in the former case, only one principal curve is derived; in the latter, three, one each for clear, partly cloudy, and cloudy weather. Therefore, his statistical comparison of the two systems appears improper and unconvincing.

NECESSITY OF SMOOTHING HYGROMETRIC CURVES

We may concede that irregular lines, such as he employs, may fit the data plotted on a particular dot chart, such as that for Medford, better than a smoothed line of continuously decreasing negative slope without sudden bends or angles, while at the same time we maintain the position that the smoothed line accords better with physical law. The fact that "upward bends and twists" occur at times in thermograms, as Ellison states in memorandum relative to my position, is immaterial; since the hygrometric dot chart does not show the course of temperature fall through the night, but the morning minimum temperature that follows certain evening dew point and relative humidity values.

Consider, for example, the S-shaped irregularity already referred to. Assume three different evenings on which the dew point had the same value, 30. On the first evening let the relative humidity be 22 per cent (the evening current temperature being, therefore, 70); the indicated morning minimum is, then, 30+4=34 according to the S-shaped curve. On the second evening let the relative humidity be 23 per cent (current temperature, therefore, 69); the indicated minimum is 30+3=33. In the third case let the relative humidity be 21 per cent (current temperature, 71); indicated minimum, 30+3½=33½. That is, starting with the first case, we obtain an indicated decrease of ensuing minimum temperature whether we increase or decrease the relative humidity (i. e., decrease or increase, respectively, the current evening temperature). Similar anomalies are obtained by using other dew points than 30 with the same relative humidities as above. (We have used the principal—curve S—irregularity for convenience, without affecting the character of results.) Therefore, this S irregularity, and others of similar nature, require explanation, not being in accord with the general hygrometric minimum-temperature law that increase of evening relative humidity is followed by a decrease of morning minimum temperature, evening dew point being the same in both cases.

It is apparent that the S-shape is accidental—perhaps the result of one or two abnormal occasions—and would be smoothed out with increase of available data. If the values, V_h, were plotted and then smoothed, after the method used in my paper on wind velocities at New York City (11), the use of arbitrary corrections would appear as an improved method of locating the free-hand curve of best fit. In fact, by this method we can, in general, produce a better line than any hyperbola, parabola, or other line that can be expressed by a simple equation.

PREFERRED METHOD

We conclude, then, that, in general, the most accurate and convenient method of employing the hygrometric relation in minimum-temperature forecasting is as follows: Draw a smooth free-hand curve directly on the dot-chart, deciding the course of the line, not simply by the eye, but also by considering average values at each ordinate. Then supplementary curves such as data indicate would be useful may be drawn, parallel to the principal line or not according to data, for use under particular values of the evening dew point (and of other meteorological conditions as well). Averages, used in locating both principal and special curves, may be simply arithmetical means, but would better be medians or weighted means; least-square methods might be used in finding the best values in certain cases. If simple

equations, such as those of parabolas or hyperbolas, can be fitted to our curves, the fact is interesting and perhaps of value; but knowledge of the equations will evidently increase neither accuracy nor convenience of prediction.

RELATION BETWEEN DEW POINT, RELATIVE HUMIDITY, AND CURRENT TEMPERATURE

Let us examine the relation, already referred to, between relative humidity and current temperature, dew point keeping constant values. From the definition of relative humidity we have

$$e=\frac{h}{100(E)}$$

where h is relative humidity, E is the vapor pressure of saturation at the current temperature, t, and e is the cur-

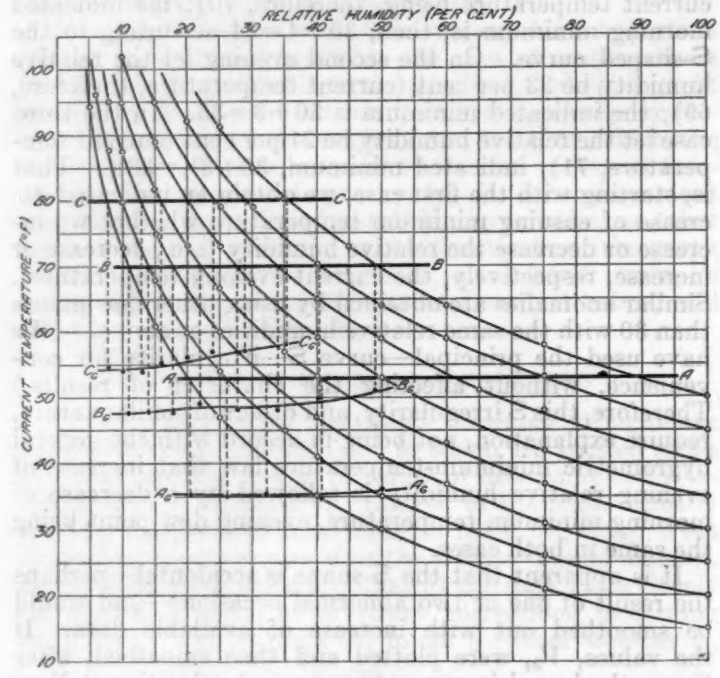


FIGURE 2.—Relation between dew point, relative humidity, and current temperature

rent vapor pressure. e is a function of the dew point, d, and may be obtained from vapor-pressure tables when d is given (10). If h be given also, we can now find E by substituting for e and h in the above equation. Having obtained E, we may now interpolate the value of t from vapor-pressure tables; e. g., having given the dew point, 30°, and relative humidity, 40 per cent, find the current temperature, t. From (10) we find

$$E=\frac{100\times 0.164}{40}=0.410$$

which corresponds to a temperature of approximately 53.5°. Keeping the dew point constant at 30°, we find that at 20 per cent relative humidity t is 73; while with h at 75 per cent, t is 37, etc. Values of t obtained thus for dew points at 5° intervals from 15 to 50 have been plotted on Figure 2, above; then smooth curves were drawn for each dew-point value, eight curves in all. Having d and h, we may now interpolate t directly from these curves.

TRANSFORMATION OF THE HYGROMETRIC FORMULAS TO THE CURRENT - TEMPERATURE FORM — ALGEBRAIC METHOD

The hygrometric minimum-temperature relation we have discussed may be expressed in general terms, thus:

$$y-d=F(h) \qquad \text{(Form A)}$$

where y, d, and h represent the same elements as above, whatever be the form of the curve of best fit. If d be variable we have

$$y=f(h, d) \qquad \text{(Form B)}$$

From the definition of relative humidity we have, as before,

$$h=100\frac{e}{E}$$

If the dew point be constant, e is also constant, and we have $h=G(t)$, since E is a function of the current temperature, t. Then Form A reduces to

$$y=\phi(h)=\psi(t) \qquad \text{(Form C)}$$

That is, in such cases, the minimum temperature is a function of the current temperature at the time of the (evening) observation. We may then transform any hygrometric equation from the usual Form A to the temperature Form C by substituting in the former the value of h obtained from the relation, $h=G(t)$, which may be expressed for a particular dew point as the equation of the curve for that dew point plotted on our Figure 2. Thus, fitting a rectangular hyperbola to the curve for dew point 30°, we have the following equation:

$$(h+24)(t-5.5)=3{,}037.5$$

or

$$h=\frac{3{,}037.5}{t-5.5}-24.$$

Substituting this value of h in the hyperbolic equation for Grand Junction, Colo. (p. 499 of (9)), we have

$$Y=\frac{738}{h+8}-7=\frac{738}{\frac{3{,}037.5}{t-5.5}-24+8}-7=$$

$$\frac{738\,t-4{,}059}{3{,}125.5-16\,t}-7=\frac{140{,}105}{3{,}125.5-16\,t}-53=$$

$$\frac{8{,}757}{t-195}-53$$

approximately, from which

$$(Y+53)(t-195)=-8{,}757$$

which is the equation of another rectangular hyperbola. Differentiating, we have

$$\frac{dY}{dt}=\frac{8{,}757}{(t-195)^2}$$

slope of the curve; and

$$\frac{d^2Y}{dt^2}=\frac{-2\,(,757)\,(t-195)}{(t-195)^4}=\frac{-17{,}514}{(t-195)^3}$$

rate of change of slope, which is positive when t lies be-

tween 0 and 195. When t is small, $\frac{d^{2Y}}{2}$ is also small; even when t is as great as 95, $\frac{d^{2dt}Y}{dt^2}$ is less than 1/57. Therefore, when the current temperature, t, lies between 0° and 95° the slope increases very slowly and we have, practically, a straight line.

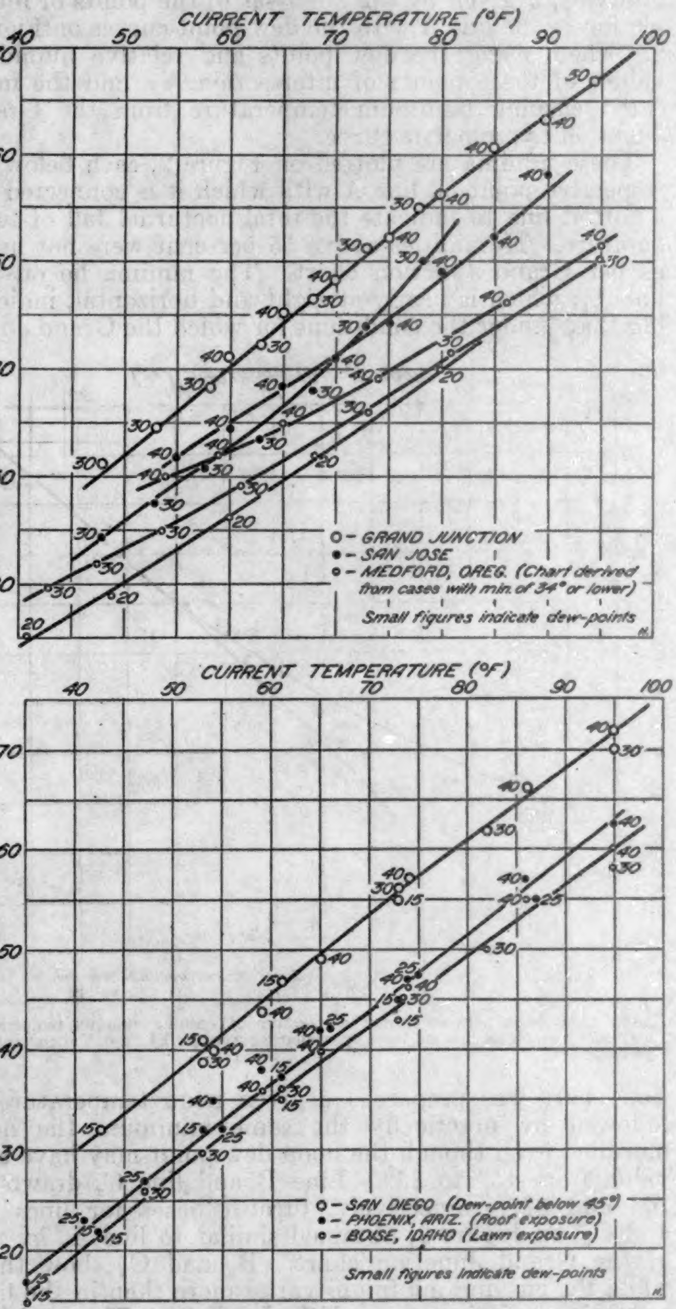
GRAPHICAL TRANSFORMATION

We can more readily transform the hygrometric equation of the Form A to the temperature form C by graphical methods. Assuming any particular dew point and relative humidity, we determine from the hygrometric formula or curve for the particular station and conditions in mind, the corresponding indicated minimum temperature, and from our curves of Figure 2 the corresponding current temperature. Then plot on a dot chart the current-temperature and minimum-temperature values so found. If we keep the dew point constant (i. e., consider other cases with the same evening dew point) and allow the relative humidity, and consequently the current (evening) temperature, to vary, we obtain a series of corresponding current-temperature and minimum-temperature values which may be plotted as a series of points on our dot chart. We may then draw through these points a line for use when the dew point is of the value chosen. A series of points so obtained for dew point 30° and another series for 40° are plotted on Figure 3, using the same noon hygrometric chart for Grand Junction, Colo., as was used in obtaining the hyperbolic equation already employed for that station; and we find that the points we have plotted lie on a straight line, practically. This agrees with the result already obtained by algebraic substitution. Not only this; but it is noted, also, that the points for 40° dew point lie on practically the same line as those for 30°. Hence, one straight line has been drawn for use with both dew points.

On Figure 3 have been plotted, also, points obtained similarly for the same dew points, using the curve for San Jose, Calif. (9, p. 500). The two sets of points lie on lines that are nearly straight, though some tendency to hyperbolic form is noted; but the two lines intersect, showing that increase of dew point does not, at all current evening temperatures, cause an increase in the minimum indicated by this San Jose chart. Further, on Figure 3, have been plotted similar data for Medford, Oreg., using the hyperbolic curve of Figure 1, for dew points 20°, 30°, and 40°. Each set of points lies on a practically straight line; the three lines are nearly coincident at higher temperatures, but diverge somewhat at lower. On Figure 4 we have similar sets of points for 15°, 25°, or 30°, and 40° dew point at Phoenix, Ariz. (roof exposure); Boise, Idaho (lawn exposure); San Diego, Calif. (dew point below 45), using charts for those stations in Supplement 16; the points for each station lie on or near a practically straight line drawn on the chart.

In all cases on Figures 3 and 4 the hygrometric charts used have been presented by their authors for use at any dew point, at least none was specified, except in the case of San Diego, where an upper limit is given higher than any we used. On Figure 5 is presented a series of points determined similarly to those of Figures 3 and 4, for El Paso, Tex., using Figures 8 and 9 of Supplement 16, which are presented for use within certain dew-point limits; considering dew points 15, 25, and 40, we get points that lie on or close to a straight line at higher temperatures, but note considerable divergence at low.

It must be borne in mind that the points we have plotted on Figures 3, 4, and 5 will give, under given conditions of dew point and relative humidity, exactly the same indicated minimum temperatures as will the hygrometric charts from which these points have been



FIGURES 3 and 4.—Relation between current temperature and ensuing minimum temperature, derived from hygrometric curves by graphical method; dew points constant

derived. We have shown results of keeping the dew point constant [3] and allowing the relative humidity (and, consequently, the current temperature) to vary; let us now keep the temperature constant and show results of allowing the dew point (and therefore the relative humidity) to vary.

[3] Because of criticisms that have been made, it seems necessary to state that we have not stated nor assumed constancy of dew point through the night. The terms "constant" and "vary" refer, of course, to employing the same or different values in our formulas.

EFFECT OF CHANGING DEW POINT ONLY

For instance, take the chart for Grand Junction, already used. The effect of keeping the dew point constant at either 30° or 40° is shown on Figure 3. If we keep the current temperature constant at 53 and allow the dew point to vary, the relative humidity, at 5° dew-point intervals, is given by the abscissas of the points of intersection of the line A with the dew-point curves on Figure 2. Then, using the dew points and relative humidity values of these points of intersection, we find the indicated ensuing minimum temperature from the Grand Junction hygrometric curve.

These minima are plotted on Figure 2, each below its respective point on line A with which it is connected by a dotted line to indicate the total nocturnal fall of temperature. Humidities above 55 per cent were not used, as per Grand Junction chart. The minima lie on the line A_g, which is nearly straight and horizontal, indicating that (under the conditions for which the Grand Junction chart was prepared) a given noon temperature is followed by practically the same minimum the next morning, even though the noon dew point may have any value from 15° to 35°. Line B and line C, drawn at 70° and 80°, respectively, furnish bases for lines B_g and C_g, on Figure 2, obtained similar to line A_g by use of the Grand Junction chart. B_g and C_g show that, while the ensuing minimum varies more than in the first case, the variations are relatively slight. Thus, with a noon temperature of 70°, the indicated minimum changes only 4° when the dew point at noon has values from 15° to 50°.

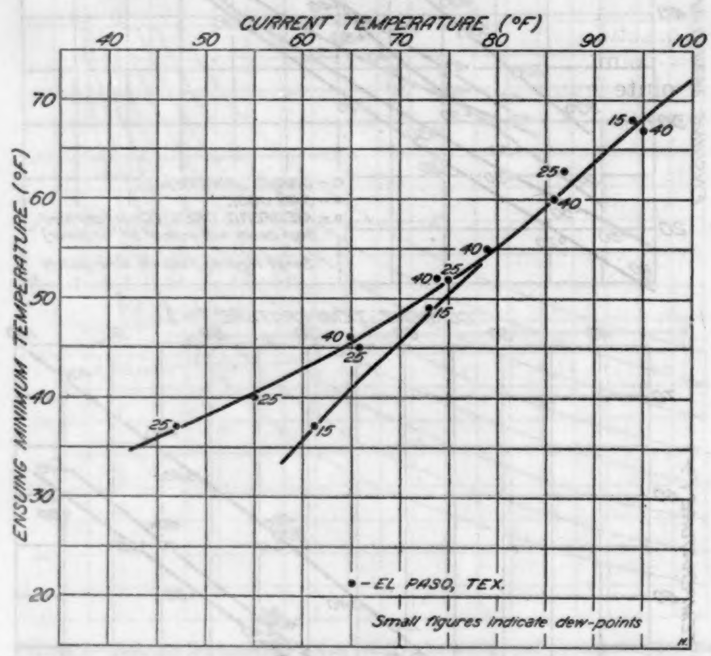


FIGURE 5.—Relation between current temperature and ensuing minimum temperature derived by graphical method from hygrometric curves for El Paso, Tex.; at certain dew points

COMPARISON OF DEW-POINT AND TEMPERATURE EFFECTS

Using the same San Diego chart as before, we find that a current temperature of 61° and dew point 30° indicate a minimum of 47°, which is plotted on Figure 6 (S. D.). Then, keeping the dew-point constant at 30, we raise the current temperature 5° to 66°, for which the indicated minimum is 50.5, which is plotted on the fifth ordinate to the right of the one first used. Then lowering the current temperature to 56, we find the indicated minimum to be 41, which is plotted on the fifth ordinate to the left of the original. Then the line through these 3 points shows the rate of change of minimum when current evening temperature varies with constant dew evening point, 30°. Similarly, we find the indicated minimum when the temperature is kept constant at 61 while the dew point is raised 5 above and then lowered 5 below 30°, and plot these minima on the fifth ordinates to the right and left of the original, as before. Then the line drawn, dotted, through these two points and the starting point (47 on the original ordinate) shows the rate of change of minimum when the dew point has different values, current temperature remaining constant. By comparing the slopes of the two lines we have now obtained we may compare dew point effect with that of current temperature. Similar lines, using the same dew points and current temperatures, have been drawn on Figure 6 for Grand Junction, Colo., San Jose, Calif., El Paso, Tex., Phoenix, Ariz., and Medford, Oreg., together with other similar diagrams using other basic dew points and temperatures, including two diagrams for Boise, Idaho.

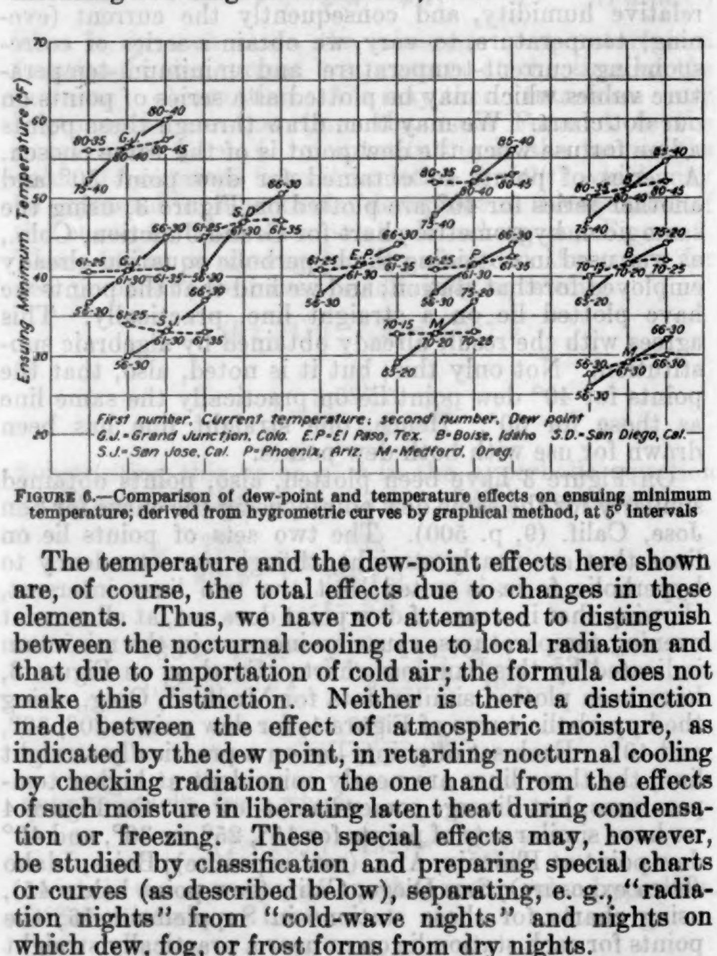


FIGURE 6.—Comparison of dew-point and temperature effects on ensuing minimum temperature; derived from hygrometric curves by graphical method, at 5° intervals

The temperature and the dew-point effects here shown are, of course, the total effects due to changes in these elements. Thus, we have not attempted to distinguish between the nocturnal cooling due to local radiation and that due to importation of cold air; the formula does not make this distinction. Neither is there a distinction made between the effect of atmospheric moisture, as indicated by the dew point, in retarding nocturnal cooling by checking radiation on the one hand from the effects of such moisture in liberating latent heat during condensation or freezing. These special effects may, however, be studied by classification and preparing special charts or curves (as described below), separating, e. g., "radiation nights" from "cold-wave nights" and nights on which dew, fog, or frost forms from dry nights.

In each diagram of Figure 6 the slope of the temperature line is much greater than that of the dew-point line. The former slope is 0.6 or more, indicating that a change of 10°, for instance, in the current temperature is followed by a change of at least 6° (in the same direction) in the ensuing minimum. The dew-point line slope is generally not above 0.1 or 0.2, sometimes being 0 or even negative, indicating that a change of 10° in the dew-point is generally accompanied by a change of not more than 1° or 2°, sometimes no change at all, in the ensuing minimum. We conclude, therefore, that current temperature is generally much more important than the dew-point in hygro-

metric formulas. In other words, at the stations, during the times of year and under the meteorological conditions for which the hygrometric charts we have transformed and otherwise examined were prepared, the minimum temperature is higher on one day than on another mainly because the preceding day or evening was warmer in the former case than in the latter, rather than because of differing evening dew points.

SYSTEM BASED ON PRECEDING TEMPERATURES

Since the minimum results from cooling from some higher preceding temperature, and since we have shown that changes in the latter greatly affect the ensuing minimum, we may logically advocate the plotting directly of the relation between current and ensuing minimum temperatures, thus obtaining such curves as those of Figures 3, 4, and 5. Since we obtain the minimum directly, and since straight-line relations are indicated, the method will be simpler than the hygrometric.

We should expect that, since our curves of Figures 3, 4, and 5 have been derived by an indirect method, curves that would fit the original data still better could be obtained directly. The temperatures used as the independent variable on these charts are the current temperatures at the times of observations, which differ considerably among the several stations considered, according to local mean time and with reference to the times of sunset, etc. At Grand Junction we used observations taken at local mean noon; at Medford, at 5 p. m., Pacific standard time; at San Jose, at 4:32 p. m., local mean time; at other stations, evidently at the time of the p. m. simultaneous observations of the Weather Bureau, which are later, according to local time, than are those at San Jose.

Although the time of maximum temperature varies more or less from day to day, even in fair weather, we may consider the prediction of the minimum from the preceding maximum temperature as based on the current temperature at the time of maximum, and thus include the maximum-minimum under the general method based on preceding temperatures. Since the maximum-minimum was proposed by me many years ago (in 1911, in the same paper in which my experiences with the dew-point formula were reported), and has since then been successfully used by me and others in actual forecasting, we may properly consider that system first. It has been explained since 1911, with some modifications and additions (2), (3), and (6).

The relation between maximum and ensuing minimum temperature was plotted on dot charts, a separate chart for several types of weather determined according to cloudiness, pressure, and wind conditions. Since straight-line relations were found (as we have herein determined indirectly for current temperatures generally) the several formulas are of the simplest type, $Y=bX+a$, where X is the daily maximum temperature, a and b are constants, and Y is the ensuing minimum temperature. A series of corrections, one for each of four groups of dew-point values, provided for variations in atmospheric cooling. The fact that later investigations at Grand Junction showed that the dew-point effect is unimportant in the hygrometric formulas for that station agrees with results we have obtained in transforming one of those formulas. (See (6), p. 41.) Thus the maximum-minimum method as proposed by me provided for the effects of "other conditions" besides the maximum temperature upon the following minimum, dew point being specifically included.

The maximum-minimum formulas and charts derived for Grand Junction and substations in vicinity thereof were successfully used in minimum-temperature forecasting (in connection with hygrometric formulas) for several years by me; also, they were so employed by my successor, Mr. A. M. Hamrick (6) and (7). I have successfully used a similar method at San Jose, Calif., during the past eight years. And Cook found the maximum-minimum relation valuable in the Red River Valley of the North (8), although he did not, apparently, consider dew-point effects or classify according to weather types.

ELLISON'S CRITICISM OF THE MAXIMUM-MINIMUM METHOD UNWARRANTED

Ellison has, therefore, adopted another untenable position when he states that the maximum-minimum formulas "appear to be faulty at their source" because "with any given maximum temperature a variety of values of absolute humidity are observed in practice * * * and consequently a variety of minimum temperatures are experienced." (5), p. 488. A system based on faulty principles could not be successfully used in practical work, as has the one in question. Also, the dew-point corrections, which provide for any possible absolute humidity effects, were included in the system as described in my papers (3) and (6) referred to by him under Nos. 22 and 31. Further, it is believed that my "application of a complex system of type classification" "in the endeavor to improve the usefulness of the basic relationship" of the maximum-minimum method (as well as of the hygrometric) should be still further extended; since neither hygrometric nor current-temperature system shows directly the effects of special values of other than basic conditions; whereas these effects can be readily shown by special charts, curves, or corrections for such special values, as is illustrated below.

THE GENERAL METHOD BASED ON PREVIOUS TEMPERATURES

In deriving other types of current-temperature formulas from original data, as suggested above, our methods may be similar to those used with the maximum-minimum. That is, we plot on a dot chart the individual observations, which may have been previously classified according to some system found desirable, current temperatures preferably as abscissas and ensuing minimum temperatures as ordinates. In order to determine a desirable classification system the dots for each observation may be entered in such a manner, and may be accompanied by such auxiliary entries, as to indicate the accompanying conditions that might affect the minimum temperature.

CLASSIFICATION ACCORDING TO TYPES OF CONDITIONS

For example, on Figure 7 entries have been made, based on the regular post meridian observations at San Jose, Calif., during April for five years. Cases when skies were clear are indicated by being plotted with small circles, while cloudy cases are entered with dots. In each case the post meridian dew point is entered at its proper cross or dot on the chart. Plainly we see that the clear cases tend to be grouped about a straight line, while the cloudy cases are relatively scattered and mostly at higher levels. It is also noted that when the dew point is below 40° the minimum temperature is usually lower than in other cases.

As the next step we may make separate charts for cloudy and for clear cases, using data for other Aprils in order to have a good supply of dots; we may well pre-

pare two clear charts, one for cases with dew point above, and one for cases with dew point below, 40°. We may have a separate chart for cases in which the sky was clear in the evening but became cloudy during night, and another for the reverse, etc. And at each point on these charts we may enter, or indicate by symbols or by colored ink or in other ways, the dew point, the barometric pressure, the wind, the soil conditions, precipitation, fog, or any other data that may possibly show effect on the minimum temperature; not only evening values, but also changes, of certain conditions may be valuable.

Possibly simply a cursory examination will determine the influence of some factor, as in the case of clear weather on our chart. It may be necessary to compute averages for certain elements; for instance, we might compute the average dew point for cases plotted in each 5° square, and thus determine the dew-point effect. (See also above, under Preferred Method.) Such possible factors as our trial charts show to be ineffective may now be discarded, and we may prepare a final set for charts, a separate chart for each weather type formed by combining the

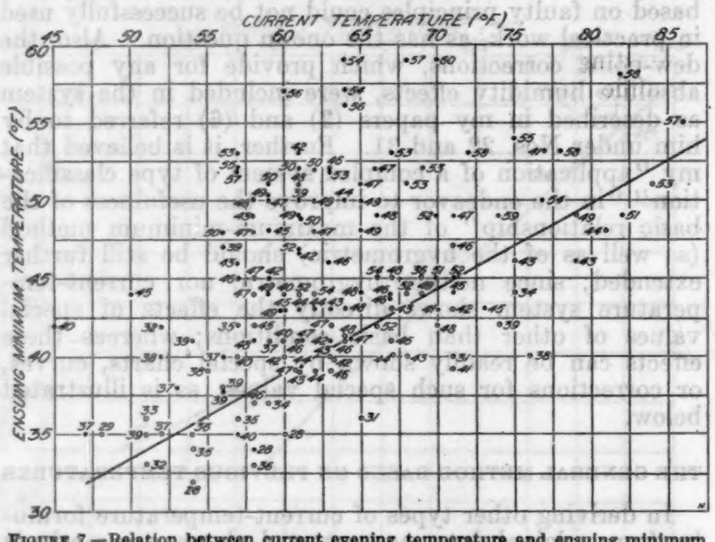


FIGURE 7.—Relation between current evening temperature and ensuing minimum temperature at San Jose, Calif., during April

elements we have found effective, or a combined chart for such types as can readily be combined.

We then draw a line of best fit to each group of plotted data. If types be combined we may have two or more lines fitting different portions of the chart. For instance, if we combine on one chart cases for all dew points that occur, we may have a line for the lower dew points and one or more other for higher dew points.

Even after progressing thus far we find that the plotted dots do not all lie on the line of best fit, though they are on an average closer than were those on the original chart to its best line; we still find that a given current temperature was followed in different cases by different minima. By study of the individual cases represented by the individual dots, especially those farthest removed from the line of best fit, we may discover the causes of the observed variations; then we may form a correction law or curve or, if data be sufficient we may draw a special chart or charts showing the effects of the newly discovered cause. Thus the average variation of dots from the line of best fit will be decreased as our classification becomes more complex.

CONCLUSION

We have considered at the beginning of this paper the dew-point formula or relation, in which the dew point is considered all important. Then we examined the hygrometric formulas and curves, in which the dew point is nominally of great importance but actually, as we have found, of secondary effect. Finally we have the temperature formulas, in which dew point is assigned definitely a secondary place, although provision is made for any moisture effects that may occur. We may have been surprised to find that the dew point does not appear prominently on our charts, in view of the undoubted importance of water vapor in retarding radiation and of the large amount of latent heat liberated during condensation and freezing. Experience has shown that minimum-temperature formulas do not give sufficiently accurate indications for satisfactory work in actual forecasting, unless modified; and minimum-temperature forecasters generally consider formulas as only approximate, modifying results according to special rules or "experience." Classification of conditions and the use of auxiliary curves furnish a means of systematic mathematical expression, quantitatively, of any modifying influence that may be discovered at any station in any formula, whether by study of weather maps or otherwise. Thus any forecaster may make his discoveries available to all students of minimum temperature forecasting, and the necessity of "esoteric interpretation" of modifying influences may be reduced. (5, p. 486.)

The general method of predicting minimum temperature from preceding temperature is logical and direct. The effect of any other independent variable upon the minimum temperature may be shown by classification of cases into groups; and this classification may be enlarged or narrowed as conditions at any particular station may require. Thus the method has characteristics fitting it for general use. Even though complicated classification may be required in some cases, the system is as simple as physical conditions permit, since if any effective variable condition is not provided for in a forecasting system, that system will not be as accurate as possible in actual use. The effects of conditions found important may be shown on separate charts or by auxiliary or correction curves, which will or will not be parallel to the basic curve according to indications of data used.

If we find in any case a straight-line relation, the corresponding formula is simple and its use is convenient. If our line be parabolic or hyperbolic, or of some other fairly simple form, use of the formula is somewhat inconvenient. If we have, also, a set of numerical corrections, inconvenience is considerably increased thereby. If we use instead of the formula, the dot chart itself, on which has been drawn, perhaps free-hand, the best fitting curve, whose equation need not be known, we not only obtain immediately our result, but also observe what dependence may be placed on different parts of the curve. If in addition we enter additional information relative to special conditions that preceded certain minima (especially for points farthest from the curve) we may be able to improve our forecasts still further. Our suggested methods imply a large amount of preliminary labor in studying weather maps and data; but the forecaster needs all possible assistance in the

complicated and difficult problem of minimum-temperature prediction.

As additional information in connection with this paper I include herewith a chart, Figure 8, showing the relation between the daily maximum temperature at the Weather Bureau Office, Mobile, Ala., and the ensuing morning minimum temperature at one of the fruit-frost stations at Seven Hills, Ala., 18 miles distant; using data for the winter of 1929–30 (Nov. 19–Feb. 18, 3 months). This is a chart using all data in accordance with the suggested system; and shows that the maximum-minimum form of the general temperature method is applicable not only in the Far West, but in the humid Gulf Coast region.

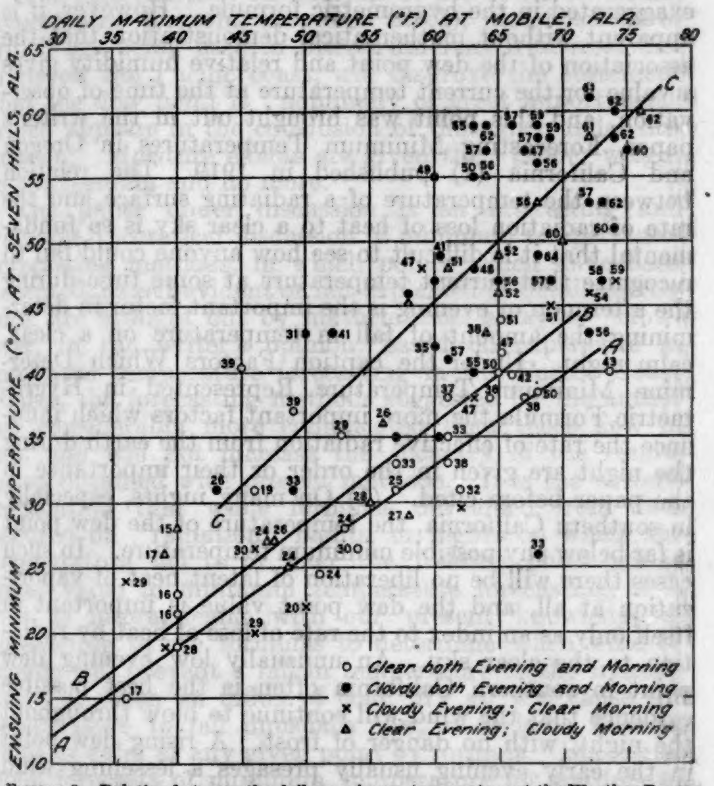


FIGURE 8.—Relation between the daily maximum temperature at the Weather Bureau Office, Mobile, Ala., and the ensuing minimum temperature at Seven Hills, Ala., Nov. 19, 1929, to Feb. 18, 1930

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DISCUSSION

By FLOYD D. YOUNG

[Weather Bureau Office, Medford, Oreg., April 30, 1930]

A great deal has been written about formulas of different types for use in minimum temperature forecasting, but very little has been said about the difficulties in the way of applying formulas in actual practice. The impression has become rather general that this type of forecasting is a simple matter, presenting few, if any, of the difficulties met with in the preparation of other types of weather forecasts. The feeling has been that weather conditions in the fruit-growing valleys of the Pacific Coast States are "settled" and that satisfactory minimum temperature forecasting is only a matter of applying a formula based on an observation made at some time in the afternoon or evening.

The initial experience of the writer with the hygrometric formula at Medford in 1917 (1) inclined him somewhat toward this belief, but it was soon recognized that the formula was valuable only as a starting point in practical forecasting. The experience of 14 years in this work, covering 16 different fruit-frost districts, has served to strengthen this conclusion. Most minimum temperature formulas are based altogether on data for nights when the temperature actually falls to the freezing point or lower in the district for which it is developed. Such nights usually make up only a very small percentage of the total during a frost season. On most nights the temperature is prevented from falling to the freezing point by wind, clouds, fog, or other agency.

Even if we could develp a formula or series of formulas that would give perfect results on frosty nights, we still would be faced with the necessity for determining whether the formula would have application on a particular night. Herein lies one of the most difficult problems in minimum temperature forecasting. The practical prediction of minimum temperatures presents different problems in different districts. Forecasting is more difficult in some districts than in others, but every section has its own peculiar local conditions which must be thoroughly understood before the forecaster can feel that he is approaching the maximum possible accuracy.

If all the nights during the frost season were calm and clear, temperature ranges between maximum and minimum could be determined with mathematical precision. However, it is seldom indeed that we approach these ideal conditions. For example, at Medford there are few frosty nights during the spring frost season without some cloudiness. It may be cloudy at the time the forecast is made, or even raining or snowing, with the current temperature in the lower thirties. If the sky clears, as it often

does, it is sure to freeze; if it remains overcast there will be no danger. If a study of the weather map and all other available data brings the decision that the sky will clear before morning, the question arises "When will the sky clear?" If it clears at 9 p. m., the temperature obviously will fall lower than it will if clearing comes at 2 or 3 a. m.

In southern California the opposite condition is often met. The sky is clear and the current temperature is low at the time the forecast is made, but the barometer is falling and the weather map shows a low-pressure area centered over northern California and spreading rapidly southward. The sky is almost sure to become overcast before sunrise, but when will the clouds form? They have come too late on many nights to prevent a fall in temperature below the danger point. On some such nights weather conditions have changed so rapidly that it has been necessary to extinguish the orchard heaters in a downpour of rain. When the temperature falls steadily at the rate of 3° or 4° an hour as long as the sky remains clear, an error of several hours in estimating the time of clouding over will give the forecaster's reputation a severe setback.

On another evening in southern California a desert wind may be blowing. Its velocity is anywhere from 15 to 30 miles per hour. The dew point is perhaps 10° above zero and the current temperature is in the forties. As long as the wind continues the temperature will remain practically stationary. If the wind lulls, the temperature will fall with almost unbelievable rapidity. The cessation of these winds is often sudden and complete. If the forecaster decides the wind will not last through the night, he must make some sort of an estimate of the time it will cease.

In the San Joaquin Valley, Calif., dense fog may form over a part of the valley floor during the night, but the hillsides and other parts of the valley floor remain clear. The problem, then, is to decide where and what time of night the fog will form, and how far under the fog-covered area the influence of the cold air draining from the slopes will extend.

These are a few of the difficulties which must be faced in making practical minimum temperature forecasts. There are many others of lesser importance. The solution of these problems will be found only in an intelligent use of the weather map and aerological data, together with as complete a knowledge of the district as possible. Formulas are of little value in dealing with these special conditions. The writer does not agree with Mr. Nichols' statement that "classification of conditions and the use of auxiliary curves furnish a means of systematic mathematical expression, quantitatively, of any modifying influence that may be discovered at any station in any formula." The statement may be true in a literal sense, but the number of classifications and auxiliary curves necessary would approximate the number of nights on which the special conditions prevailed. In the writer's opinion it is utterly impracticable to reduce all minimum temperature forecasting factors to a mathematical basis. A dozen or more curves may be drawn to represent different conditions or different influences which may affect the minimum temperature, but it will still be necessary for the forecaster to decide which one of these curves he shall use on a particular night. It is almost as important to issue a reassuring forecast when local conditions alone are threatening, as it is to issue a warning when crop protection is necessary.

The writer's experience has been that the most successful and practical method of making minimum temperature forecasts is to develop a formula based on all available data to indicate what the minimum temperature will be under more or less ideal conditions, that is, when the temperature fall after sunset is least affected by clouds, wind, or other such factors. The effect of modifying influences is then estimated from the weather map and all other sources at hand, and the formula estimated is raised or lowered accordingly.

In the paper under discussion the author has demonstrated mathematically the relation between the hygrometric formula and the current temperature formula and intimates that the importance of the dew point has been exaggerated in the hygrometric formula. However, it is apparent without mathematical demonstration that the association of the dew point and relative humidity gives a value for the current temperature at the time of observation, and this point was brought out in the writer's paper, Forecasting Minimum Temperatures in Oregon and California (1) published in 1919. The relation between the temperature of a radiating surface and the rate of radiation loss of heat to a clear sky is so fundamental that it is difficult to see how anyone could fail to recognize that current temperature at some time during the afternoon or evening is the important factor in determining the amount of fall in temperature on a clear, calm night. Under the caption Factors Which Determine Minimum Temperature Represented in Hygrometric Formula the more important factors which influence the rate of effective radiation from the earth during the night are given in the order or their importance in the paper before cited. (1) On many nights, especially in southern California, the temperature of the dew point is far below any possible minimum temperature. In such cases there will be no liberation of latent heat of vaporization at all, and the dew point value is important in itself only as an index to the rate of loss of heat by radiation to the clear sky. An unusually low evening dew point in southern California often is the best possible evidence that the wind will continue to blow throughout the night, with no danger of frost. A rising dew point in the early evening usually presages a lessening wind velocity and freezing temperatures.

On the other hand, higher dew points are usually important in determining the temperature fall. For example, the temperature has never fallen to 32° F. or lower in the Pomona fruit-frost district when the 4:40 p. m. dew point has been 50° F. or above during the past 14 winters, no matter what the current weather conditions have been at the time of observation. During the same period there has never been a freezing temperature in the Medford district during the spring frost season when the 4:40 p. m. dew point has been 45° F. or higher.

In connection with the statement in the conclusion of the paper under discussion "We may have been surprised to find that the dew-point effect does not appear more prominently on our charts, in view of the undoubted importance of water vapor in retarding radiation and of the large amount of latent heat liberated during condensation and freezing," attention might be called to studies of changes in dew point during the night at Medford and Pomona discussed briefly in the writer's paper in Supplement 16 of the MONTHLY WEATHER REVIEW. (1) It was shown that rapid changes in dew point at Medford after the evening observation are the rule under certain conditions, and that it is unsafe to draw any conclusions

regarding the relative effects of high or low dew points on the nocturnal temperature fall from 4:40 p. m. data.

For example, the dew point on April 27, 1918, was 11° F. at 4 p. m. and 22° F at 5 p. m. By 7:30 p. m. it had risen to 35° F. During the rest of the night it ranged between 25° and 30° F. On the night of April 25, 1918, the dew point was 30° F. at 4 p. m. and 26° F. at 5 p. m., and varied between 26° and 32° F. during the night. In these two cases the effect of atmospheric moisture in retarding radiation, and the amount of heat liberated in condensation and freezing were practically the same, yet the values of the afternoon dew-point temperatures would indicate widely different effects.

It is believed that an analysis of the so-called Young hygrometric formula, described in (1), modifications of which are being used in fifteen different fruit-frost districts on the Pacific coast, will disprove the statement that the dew point is "nominally of great importance," which appears in the conclusion of the paper under discussion. Moisture effects are given their proper weight in the formula and no more.

The paper under discussion is an interesting and valuable theoretical discussion of minimum temperature-forecasting methods, in which points which have been accepted, as self-evident or not explained in detail heretofore, are brought out by mathematical anlaysis. However, in the writer's opinion, based on experience in minimum temperature forecasting in the Pacific Coast States, the forecasting methods suggested by the author are considerably more complicated than those now in use, and will not increase the accuracy of the results being obtained with present methods. It is the writer's contention that while formulas developed from data secured on "radiation" nights, or nights on which the temperature fell to or near the freezing point are of great value in minimum temperature forecasting, it is just as impracticable with our present knowledge of forecasting to use formulas to determine when wind or clouds will prevent a fall in temperature to the freezing point or when an influx of cold, dry air will cause the temperature to fall unusually low, as it is to forecast rains or gales at any given point by formula. Successful noon forecasts of minimum temperature for the following morning at Pomona have been made for several years when general orchard heating is in prospect, through the use of the morning weather chart alone, without the use of a formula.

In the preparation of minimum temperature forecasts in the evening, the time factor is important, since the later the forecasts are given to the public the less valuable they become. The system of forecasting used should be as simple as possible without sacrificing accuracy. The type of formula used, whether curves or equations with corrections, is entirely a matter of the personal preference of the forecaster, and is unimportant from the standpoint of results obtained.

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REJOINDER

By ESEK S. NICHOLS, San Jose, Calif., May 23, 1930

Referring to discussion by Mr. Floyd D. Young:

Mr. Young has well emphasized the complications and difficulties of minimum-temperature forecasting, which have occasioned the large amount of study that has been devoted to the subject without, we may say, completely solving our problem. Also, he has very properly emphasized the use of the weather map, which is of course indispensable.

In his ninth paragraph he advises raising or lowering the formula estimate according to estimated effects of modifying influences. This implies a quantitative estimate in degrees of such effects, and it is difficult to see why an auxilliary curve or curves can not be drawn to express them. Consider, for example, the clearing conditions at Medford referred to in the last sentence of his fourth paragraph. We should have an auxilliary curve for cases when the sky clears at about 9 p. m. and another curve for use if clearing occur at 2 or 3 a. m.; deciding in the evening which if either curve to use, after considering the weather map and other available helps.

Evidently he overestimates the number of classifications and auxilliary curves that would be required; for modifying conditions fall into great classes or types, as do conditions producing rainfall, for example. Classification may be based on weather map wholly or in part; see, for example, types for Grand Junction, Colo. (3) and (6).

Mr. Young's statement regarding the importance of current temperature in determining nocturnal cooling is exactly in accord with my remark that the dew point is "nominally" of great importance in hygrometric formulas; since dew point appears prominently whereas current temperature does not specifically appear in those formulas. Also, his statement accords with my paper as a whole, since my principal purpose is, as indicated in the title and in the conclusion, to advocate the predicting of minimum temperatures from preceding, or current, temperatures and to develop a method of predicting on that basis. This paper is presented as outlining a general method of attacking the problem of minimum temperature forecasting.

WEATHER AND COTTON PRODUCTION

By J. B. KINCER

[Weather Bureau, Washington, D. C., May 9, 1930]

Two main lines of studying the relation of weather to yield of crops have been followed by investigators in several different countries. One involves an effort to establish meteorological cycles, or quasi-regular sequences, comprising a definite number of years, the recurring phases of which are supposed to show meteorological conditions quite similar to their predecessors, with a consequent reproduction of agricultural phenomena. The other has to do with the influence on production of weather during the growing season, and is usually studied by statistical determinations of the relation between weather records and yield. The ultimate goal of all such investigations is to permit a forecast of yield as far as possible in advance of harvest.

The first method has to do with some form or other of long-range forecasting of weather or of yields; that is, a determination a year or more in advance of the kind of weather, and hence yield, that may be expected for a particular season, either from past weather records or from past yield records. Clearly, the establishment of cycles or periods of this character that would give an indication of crop production far in advance, even within rather wide limits of accuracy, would be of the greatest importance. A number of such studies have been made, among which may be mentioned those of Prof. H. L. Moore, Columbia University, and Sir Napier Shaw and Sir William Beveridge, of England; but it appears the difficulty in the application of seemingly significant results lies largely in the bewildering number of weather or yield cycles apparently found.

The second method, which deals with the weather prevailing during plant development, has received the attention of a much greater number of investigators, both in this country and abroad. Various papers on the subject have been published by employees of the Weather Bureau and others from time to time, while in England the relation between weather and crops has formed the subject of the inaugural address of two presidents of the Royal Meteorological Society, Mr. Mawley, in 1898, and Mr. Hooker, 1921. Other investigators include Hall, of England; Wallen, of Sweden; Okada, of Japan; Taylor, of Australia; and Jacob, of India.

In a study of the relation of weather to the yield of crops it is necessary, because of varying weather conditions and yields over an extended area, to adopt a comparatively small geographic unit as a base. In this country unit State areas are usually considered, because considerable weather data and most yield data are normally compiled and published on this basis; otherwise, an enormous amount of labor is required to compile the necessary statistics in convenient form for study. Again, investigations are usually confined to a single State or to only a small part of the production area for a given crop. Such studies are valuable, but they necessarily have limited utility, because of the comparative unimportance of the yield of a single State, or a small area, to that for the country as a whole.

The present paper has to do with the effect of weather on the yield of cotton in the United States, and includes practically the entire producing area. Cotton is one of the most important crops grown in this country, and those interested in production are very much concerned with the prevailing weather during the growing season as affecting the progress of the crop, and providing a "pointer" to probable production. The trade spends large sums of money annually in collecting and studying current meteorological data, and prices from day to day are very sensitive to weather conditions and changes; yet, definite, concrete knowledge of the weather-cotton relation, mathematically determined, has been very meager.

The advent of the boll weevil complicated the study of weather effect on cotton production, because of the varying amount of damage done by this pest from year to year, but it was early recognized that weevil activity is also very largely a weather problem. To be of most value in indicating yield, data as to the causative factors, whether weevil or weather, must be available comparatively early in the season, and as long as possible before harvest. In the present study this desideratum was constantly kept in mind, and it will be noted that practically all requisite data are obtainable early in September for a current growing season.

There are two major influences operating to vary the production of cotton from year to year—weather and the cotton boll weevil. But weevil activity and the corresponding varying damage are dependent very largely on the weather and consequently the whole matter bases, primarily, on weather conditions, operating through a direct effect on production and an indirect effect through weevil ravages. Because of the weevil influence, it was apparent early in this study that the first problem was to establish, if possible, a relation between the weather and weevil activity, whereby this indirect influence could be approximated in season to be utilized simultaneously with weather records in direct relation to production. This was necessary because the weevil data collected by the Department of Agriculture are not available under present practices until long after cotton has been harvested.

Following this avenue of approach a working formula was first devised whereby a weevil index of yield reductions could be obtained long before these data are available by the present methods of compilation. The results, a part of this general investigation, were presented in a paper published in the MONTHLY WEATHER REVIEW for August, 1928, under title "Weather and the Cotton Boll Weevil." Weevil data are available for the 20-year period from 1909 to 1928, inclusive, and these years are included in the present paper. The weevil data used in establishing the basic equations are those reported by the Department of Agriculture, and methods of determining a weevil index from weather data for projection of the various curves, or for application to future years, are explained later in this discussion.

Broadly, we have computed from the relation of weather to yield, as determined by methods of multiple coefficients and regression constants, a set of per-acre yield indices for each of the 10 principal cotton States, representing within a very few per cent the entire cotton production of the country. The per-acre State indices are then combined, by proper weighting on an acreage basis, to form a composite, or average, per-acre yield for the entire belt. This latter, applied to the total acreage, gives, of course, a total production for the belt in pounds, which is finally reduced to standard bales. Reference to the accompanying tables indicates the procedure, as follows:

TABLE 1

NORTH CAROLINA

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	Weather data (See text description) a	b	c	d	e	f	Computed adjusted yield	Computed yield indices
	1	2	3	4	5	6	7	8	9	10	11
1909	210	0	210	5.4	7.9	67	3.0	------	------	226	226
1910	227	0	227	5.0	7.4	62	3.0	------	------	222	222
1911	315	0	315	1.3	2.8	70	3.4	------	------	311	311
1912	267	0	267	4.6	5.7	69	5.0	------	------	254	254
1913	239	0	239	4.4	4.9	65	5.8	------	------	254	254
1914	290	0	290	1.4	3.3	69	3.2	------	------	302	302
1915	260	0	260	5.6	4.4	72	3.9	------	------	285	285
1916	215	0	215	4.6	6.4	57	2.7	------	------	228	228
1917	194	0	194	2.8	6.0	54	7.0	------	------	207	207
1918	268	0	268	3.6	3.8	60	4.2	------	------	267	267
1919	266	0	266	5.3	5.0	61	1.2	------	------	265	265
1920	275	0	275	1.8	4.9	64	4.7	------	------	259	259
1921	264	4	275	4.5	3.0	64	2.8	------	------	294	282
1922	250	13	288	5.1	6.4	63	1.6	------	------	247	215
1923	290	13	334	4.3	2.4	66	4.0	------	------	302	263
1924	196	7	211	5.3	5.3	65	10.7	------	------	222	206
1925	261	8	284	2.8	3.9	69	2.0	------	------	307	282
1926	292	3	302	1.7	3.9	70	1.7	------	------	303	294
1927	238	16	284	2.5	4.9	68	2.0	------	------	281	236
1928	212	12	241	4.8	5.5	67	11.2	------	------	221	194
Sum	5,029	------	5,245	76.8	97.8	1,302	83.1	------	------	------	5,052
Mean	251	------	262	3.8	4.9	65.1	4.2	------	------	------	253

SOUTH CAROLINA

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	a	b	c	d	e	f	Computed adjusted yield	Computed yield indices
1909	210	0	210	12	4.9	73	------	------	------	211	211
1910	216	0	216	13	5.8	76	------	------	------	211	211
1911	280	0	280	8	3.8	74	------	------	------	244	244
1912	209	0	209	9	5.2	73	------	------	------	226	226
1913	235	0	235	12	4.8	74	------	------	------	215	215
1914	255	0	255	8	5.2	78	------	------	------	250	250
1915	215	0	215	9	3.3	76	------	------	------	248	248
1916	160	0	160	11	14.7	74	------	------	------	162	162
1917	208	0	208	8	6.6	70	------	------	------	213	213
1918	250	0	250	7	5.0	70	------	------	------	228	228
1919	240	3	248	10	8.9	74	------	------	------	202	196
1920	260	13	299	6	5.6	81	------	------	------	270	235
1921	140	31	204	6	7.4	74	------	------	------	234	161
1922	123	40	205	11	7.2	73	------	------	------	203	122
1923	187	27	257	8	4.5	78	------	------	------	254	185
1924	160	16	191	10	6.9	70	------	------	------	200	168
1925	160	12	182	8	3.2	57	------	------	------	187	165
1926	182	4	190	8	6.2	73	------	------	------	226	217
1927	148	27	203	13	6.4	74	------	------	------	200	146
1928	147	15	173	12	6.8	78	------	------	------	218	185
Sum	3,985	------	4,390	189	122.4	1,470	------	------	------	------	3,988
Mean	199	------	220	9.5	6.1	74	------	------	------	------	199

GEORGIA

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	a	b	c	d	e	f	Computed adjusted yield	Computed yield indices
1909	184	0	184	80.6	18.5	15.1	------	------	------	172	172
1910	173	0	173	80.6	17.9	16.5	------	------	------	165	165
1911	240	0	240	84.4	21.9	10.3	------	------	------	219	219
1912	159	0	159	83.4	17.4	17.6	------	------	------	170	170
1913	208	0	208	83.7	22.0	12.7	------	------	------	211	211
1914	239	0	239	85.2	22.5	8.9	------	------	------	229	229
1915	189	0	189	85.0	20.4	14.8	------	------	------	201	201
1916	165	3	171	86.2	19.5	21.1	------	------	------	184	178
1917	173	9	191	78.4	21.7	10.8	------	------	------	193	176
1918	190	11	214	84.1	20.1	10.6	------	------	------	207	184
1919	152	19	188	80.6	17.7	19.4	------	------	------	156	126
1920	138	31	200	79.0	20.2	13.9	------	------	------	178	123
1921	90	45	164	80.2	20.7	13.7	------	------	------	186	102
1922	100	44	179	81.0	18.9	17.3	------	------	------	170	95
1923	82	37	131	78.0	17.6	18.4	------	------	------	148	93
1924	157	15	185	79.4	19.6	13.9	------	------	------	176	150
1925	155	7	167	81.2	20.3	8.2	------	------	------	202	188
1926	180	5	190	82.9	19.1	11.4	------	------	------	194	189
1927	154	18	188	84.8	18.4	13.7	------	------	------	192	157
1928	131	14	153	79.8	18.9	17.7	------	------	------	164	141
Sum	3,259	------	3,713	1,638.5	393.3	286.0	------	------	------	------	3,269
Mean	163	------	186	81.9	19.7	14.3	------	------	------	------	163

TABLE 1—Continued

ALABAMA

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	Weather data (See text description) a	b	c	d	e	f	Computed adjusted yield	Computed yield indices
	1	2	3	4	5	6	7	8	9	10	11
1909	142	0	142	63.4	6.6	52	4.5	------	------	156	156
1910	160	0	160	61.9	3.9	56	7.1	------	------	159	159
1911	204	0	204	63.9	2.8	71	5.7	------	------	190	190
1912	172	2	176	64.6	3.6	56	5.2	------	------	179	175
1913	190	4	198	62.3	3.1	76	5.0	------	------	189	181
1914	209	6	223	63.8	1.0	78	4.2	------	------	213	200
1915	146	16	174	64.9	6.3	68	5.2	------	------	170	143
1916	79	28	110	62.2	4.3	62	16.7	------	------	116	84
1917	125	29	177	64.0	2.4	75	6.0	------	------	194	138
1918	149	12	170	61.1	2.5	68	3.9	------	------	189	166
1919	122	29	172	62.6	6.1	61	6.6	------	------	153	109
1920	111	36	174	62.3	4.9	71	5.3	------	------	172	110
1921	124	32	183	62.3	2.0	71	5.2	------	------	192	131
1922	142	26	192	66.9	6.7	64	4.4	------	------	175	129
1923	91	33	136	63.4	8.6	69	5.2	------	------	150	100
1924	154	12	175	63.3	4.2	68	3.6	------	------	186	164
1925	185	5	195	68.2	2.3	72	4.9	------	------	212	201
1926	196	3	203	61.2	3.0	70	6.1	------	------	177	172
1927	180	15	212	68.1	2.6	54	4.0	------	------	202	172
1928	145	12	165	59.8	3.6	54	5.1	------	------	164	144
Sum	3,026	------	3,541	1,270.2	80.5	1,316	113.9	------	------	------	3,024
Mean	151	------	177	63.5	4.0	65.8	5.7	------	------	------	151

MISSISSIPPI

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	a	b	c	d	e	f	Computed adjusted yield	Computed yield indices
1909	157	4	164	6.8	10.0	6.5	82.0	------	------	181	174
1910	182	15	215	3.9	4.9	6.5	79.7	------	------	204	173
1911	172	5	182	9.6	2.1	4.5	78.6	------	------	188	179
1912	173	18	211	10.3	4.4	5.1	80.7	------	------	191	157
1913	204	33	305	5.0	4.2	2.1	81.4	------	------	237	159
1914	195	24	257	4.7	1.8	2.3	82.3	------	------	264	201
1915	167	25	223	1.1	5.8	4.7	80.8	------	------	231	173
1916	125	32	184	3.0	7.4	4.1	80.4	------	------	208	141
1917	155	22	199	4.8	1.9	2.8	81.0	------	------	246	192
1918	187	10	208	7.8	1.6	3.9	79.7	------	------	215	193
1919	160	20	200	5.2	8.0	5.0	81.1	------	------	198	158
1920	145	32	214	9.5	5.9	4.5	80.2	------	------	181	123
1921	148	30	212	9.4	1.6	2.9	82.4	------	------	240	168
1922	157	28	218	5.2	5.9	3.7	80.5	------	------	209	150
1923	91	31	132	8.5	9.1	5.2	79.4	------	------	154	106
1924	176	7	190	5.0	4.5	3.5	81.2	------	------	228	212
1925	275	3	284	1.2	3.8	2.5	82.3	------	------	268	260
1926	241	6	257	3.4	3.8	3.3	80.5	------	------	234	220
1927	194	16	231	5.1	4.5	5.1	81.7	------	------	228	192
1928	176	14	205	8.9	4.3	9.3	81.7	------	------	195	168
Sum	3,480	------	4,291	118.4	95.5	87.5	1,617.6	------	------	------	3,499
Mean	174	------	215	5.9	4.8	4.4	80.9	------	------	------	175

TENNESSEE

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	a	b	c	d	e	f	Computed adjusted yield	Computed yield indices
1909	158	0	158	5.8	57.7	68.8	76.7	------	------	168	168
1910	207	0	207	5.2	56.5	64.1	77.0	------	------	162	162
1911	257	0	257	1.8	62.0	69.7	76.0	------	------	218	218
1912	169	0	169	4.0	60.6	64.4	77.4	------	------	192	192
1913	210	0	210	3.9	59.9	67.3	80.0	------	------	210	210
1914	200	0	200	2.2	59.1	72.5	79.5	------	------	227	227
1915	188	0	188	5.7	60.8	66.6	77.0	------	------	180	180
1916	206	1	209	5.1	61.9	65.5	77.9	------	------	193	191
1917	130	2	133	3.4	53.2	65.2	76.4	------	------	161	158
1918	175	0	175	3.7	62.8	69.2	74.7	------	------	197	197
1919	195	0	195	6.5	58.4	70.0	79.2	------	------	182	182
1920	185	1	187	4.2	60.2	66.2	76.6	------	------	187	185
1921	228	7	246	2.4	60.2	71.2	80.2	------	------	232	216
1922	190	9	209	4.8	62.9	69.6	77.4	------	------	204	186
1923	92	21	117	6.6	58.0	67.3	77.2	------	------	163	129
1924	170	2	174	5.8	53.6	69.0	75.7	------	------	145	142
1925	210	0	210	2.0	55.2	71.4	79.1	------	------	207	207
1926	188	2	192	2.9	59.1	65.6	77.9	------	------	200	196
1927	178	3	184	5.1	61.4	66.5	77.3	------	------	189	183
1928	185	2	189	4.9	58.2	64.8	78.3	------	------	180	176
Sum	3,721	------	3,809	86.0	1,181.7	1,354.9	1,551.5	------	------	------	3,705
Mean	186	------	190	4.3	59.1	67.7	77.6	------	------	------	185

TABLE 1—Continued

LOUISIANA

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	Weather data (See text description)						Computed adjusted yield	Computed yield indices
				a	b	c	d	e	f		
	1	2	3	4	5	6	7	8	9	10	11
1914	165	18	201	8.4	74	19.6	70.1	......	......	207	170
1915	165	20	206	6.5	74	18.5	70.2	......	......	200	160
1916	170	24	224	11.7	71	17.7	72.2	......	......	208	158
1917	210	12	239	5.9	74	21.2	71.4	......	......	231	203
1918	167	10	186	9.1	66	20.0	68.4	......	......	175	157
1919	93	25	124	13.8	51	17.2	71.1	......	......	147	110
1920	126	26	170	9.1	71	17.8	71.0	......	......	196	145
1921	114	35	175	9.5	67	17.2	71.4	......	......	186	121
1922	144	25	192	11.1	65	17.4	69.4	......	......	164	123
1923	125	23	162	14.2	67	17.5	69.5	......	......	171	132
1924	145	5	153	9.2	74	17.6	68.7	......	......	179	170
1925	232	10	258	3.6	73	20.3	74.9	......	......	256	230
1926	200	9	220	11.9	76	20.0	69.9	......	......	214	195
1927	170	12	193	12.2	62	16.0	70.3	......	......	156	137
1928	165	17	199	10.8	70	16.4	72.3	......	......	197	164
Sum	2,391	......	2,902	147.0	1,035	274.4	1,060.8	......	......	......	2,375
Mean	159	......	193	9.8	69	18.3	70.7	......	......	......	158

ARKANSAS

1909	153	6	163	8	6.8	10	56	......	......	170	159
1910	175	7	189	9	6.6	10	66	......	......	189	176
1911	190	2	194	12	1.1	6	64	......	......	208	204
1912	190	2	194	12	2.4	9	62	......	......	192	188
1913	205	3	212	6	3.3	4	62	......	......	220	214
1914	196	3	203	9	3.3	2	55	......	......	196	190
1915	180	5	190	5	5.6	9	59	......	......	196	186
1916	209	7	225	7	3.6	8	58	......	......	198	185
1917	170	10	189	9	3.2	6	59	......	......	198	179
1918	158	3	163	9	3.0	7	44	......	......	165	159
1919	155	5	164	7	6.0	10	56	......	......	178	168
1920	195	9	215	9	8.2	6	64	......	......	184	167
1921	160	22	206	9	2.2	11	59	......	......	194	152
1922	173	18	211	9	5.1	7	65	......	......	200	166
1923	98	16	117	11	8.2	9	60	......	......	162	132
1924	169	4	177	8	4.6	8	48	......	......	168	160
1925	205	2	210	6	1.9	4	60	......	......	222	218
1926	195	3	202	7	2.4	6	58	......	......	208	202
1927	157	11	177	12	6.5	9	58	......	......	162	141
1928	161	15	191	9	3.6	13	62	......	......	190	162
Sum	3,494	......	3,792	173	87.6	154	1,175	......	......	......	3,508
Mean	175	......	190	9	4.4	8	59	......	......	......	175

OKLAHOMA

1909	147	3	152	24.0	80.1	44	......	......	......	140	136
1910	200	1	203	20.7	79.8	59	......	......	......	202	200
1911	160	0	160	23.9	82.4	51	......	......	......	161	161
1912	183	1	185	23.3	78.1	56	......	......	......	183	181
1913	132	0	132	23.4	79.9	34	......	......	......	109	109
1914	212	1	215	19.0	82.9	57	......	......	......	200	198
1915	162	3	168	21.9	76.4	64	......	......	......	217	211
1916	154	4	161	23.7	79.2	47	......	......	......	151	145
1917	165	4	172	22.5	80.0	57	......	......	......	188	180
1918	92	1	93	22.9	81.8	41	......	......	......	133	132
1919	195	1	197	18.8	78.1	52	......	......	......	189	187
1920	230	9	253	20.4	78.2	62	......	......	......	215	196
1921	104	41	177	22.4	78.7	53	......	......	......	177	104
1922	103	26	140	20.0	79.8	44	......	......	......	156	115
1923	98	19	121	21.0	80.2	41	......	......	......	142	115
1924	187	4	195	22.8	80.0	50	......	......	......	164	157
1925	155	2	159	21.3	83.1	50	......	......	......	167	164
1926	181	8	197	22.5	78.2	53	......	......	......	177	163
1927	138	31	200	23.6	78.0	62	......	......	......	202	139
1928	133	26	180	22.3	77.6	55	......	......	......	185	137
Sum	3,131	......	3,460	440.4	1,592.5	1,032	......	......	......	......	3,130
Mean	157	......	173	22.0	79.6	52	......	......	......	......	156

TABLE 1—Continued

TEXAS

Year	Yield (lbs. per acre)	Weevil data	Adjusted yield	Weather data (See text description)						Computed adjusted yield	Computed yield indices
				a	b	c	d	e	f		
	1	2	3	4	5	6	7	8	9	10	11
1909	125	12	144	3.4	74.7	3.1	70.0	52	20.3	152	133
1910	145	7	159	6.5	76.3	3.9	68.9	50	19.4	171	156
1911	186	1	192	7.7	73.9	2.1	72.1	58	19.9	173	167
1912	206	3	218	10.3	73.9	2.3	65.9	49	18.9	207	196
1913	150	7	169	8.1	75.4	2.6	68.6	49	21.3	160	142
1914	184	8	208	9.3	73.7	7.7	72.3	49	16.6	203	179
1915	147	16	184	9.2	72.9	2.5	70.4	52	18.0	20[illegible]	164
1916	157	19	205	5.4	72.4	3.8	69.7	54	19.6	172	130
1917	135	7	158	3.6	74.4	2.8	68.9	46	19.6	163	140
1918	115	4	133	3.4	74.3	2.4	72.4	43	20.6	142	124
1919	140	14	178	11.4	74.3	5.3	66.9	62	19.1	203	162
1920	174	20	234	7.2	74.9	5.1	67.9	55	15.6	223	166
1921	98	34	166	7.6	73.9	1.9	69.6	56	20.1	176	105
1922	130	16	174	9.5	74.9	4.5	69.9	51	20.7	166	123
1923	147	10	183	10.0	74.4	2.0	70.4	51	19.6	186	149
1924	138	8	172	12.0	74.6	4.4	71.7	46	20.3	175	142
1925	113	2	139	4.3	80.3	2.6	72.4	47	19.5	147	122
1926	147	11	190	9.4	70.1	3.4	69.0	58	19.7	194	151
1927	129	20	186	9.6	79.1	1.6	69.1	53	20.3	172	118
1928	139	12	185	7.1	72.4	3.4	69.3	54	18.8	190	143
Sum	2,905	......	3,577	155.0	1,490.8	67.4	1,395.4	1,035	387.9	......	2,912
Mean	145	......	179	7.8	74.5	3.4	69.8	51.8	19.4	......	146

NOTE.—See context for description of data in Table 1.

COTTON ACREAGE HARVESTED (000 OMITTED)

TABLE 2

Year	North Carolina	South Carolina	Georgia	Alabama	Mississippi	Tennessee	Louisiana	Arkansas	Oklahoma	Texas	Total
1909	1,359	2,492	4,674	3,471	3,291	735	......	2,218	1,767	9,660	29,667
1910	1,478	2,534	4,873	3,560	3,317	765	......	2,238	2,204	10,060	31,029
1911	1,624	2,800	5,504	4,017	3,340	837	......	2,313	3,050	10,943	34,428
1912	1,545	2,695	5,335	3,730	2,889	783	......	1,991	2,665	11,338	32,971
1913	1,576	2,790	5,318	3,760	3,067	865	......	2,502	3,009	12,597	35,484
1914	1,527	2,861	5,433	4,007	3,054	915	1,299	2,480	2,847	11,931	36,354
1915	1,282	2,516	4,825	3,340	2,735	772	990	2,170	1,805	10,510	31,035
1916	1,451	2,780	5,277	3,225	3,110	887	1,250	2,600	2,562	11,400	34,542
1917	1,515	2,837	5,195	1,917	2,788	882	1,454	2,740	2,783	11,092	33,203
1918	1,600	3,001	5,341	2,570	3,138	902	1,683	2,991	2,998	11,233	35,457
1919	1,490	2,835	5,220	2,791	2,848	758	1,527	2,725	2,424	10,476	33,094
1920	1,587	2,964	4,900	2,858	2,950	840	1,470	2,980	2,749	11,898	35,196
1921	1,403	2,571	4,172	2,235	2,628	634	1,168	2,382	2,206	10,745	30,144
1922	1,625	1,912	3,418	2,771	3,014	985	1,140	2,799	2,915	11,874	32,453
1923	1,679	1,965	3,421	3,079	3,170	1,172	1,405	3,026	3,197	14,150	36,264
1924	2,005	2,404	3,046	3,055	2,981	996	1,616	3,094	3,861	17,175	40,233
1925	2,017	2,654	3,589	3,504	3,466	1,173	1,874	3,738	5,214	17,608	44,837
1926	1,985	2,648	3,965	3,651	3,752	1,143	1,979	3,790	4,676	18,374	45,963
1927	1,727	2,421	3,412	3,225	3,338	965	1,542	3,048	3,601	16,176	39,455
1928	1,890	2,355	3,719	3,595	3,994	1,086	1,985	3,610	4,249	17,766	44,249

PERCENTAGE OF TOTAL ACREAGE HARVESTED, BY STATES

TABLE 2 (a)

1909	4.6	8.4	15.7	11.7	11.1	2.5	......	7.5	6.0	32.5	......
1910	4.8	8.2	15.7	11.5	10.7	2.5	......	7.2	7.1	32.4	......
1911	4.7	8.1	16.1	11.7	9.7	2.5	......	6.7	8.9	31.8	......
1912	4.7	8.2	16.2	11.3	8.8	2.4	......	6.0	8.1	34.4	......
1913	4.5	7.9	15.0	10.6	8.7	2.4	......	7.0	8.5	35.5	......
1914	4.2	7.9	14.9	11.0	8.4	2.5	3.6	6.8	7.8	32.8	......
1915	4.1	8.1	15.5	10.8	8.8	2.5	3.2	7.0	6.1	33.9	......
1916	4.2	8.0	15.3	9.3	9.0	2.6	3.6	7.5	7.4	33.0	......
1917	4.6	8.5	15.6	5.8	8.4	2.7	4.4	8.2	8.4	33.4	......
1918	4.5	8.5	15.1	7.2	8.9	2.5	4.7	8.4	8.5	31.7	......
1919	4.5	8.6	15.8	8.4	8.6	2.3	4.6	8.2	7.3	31.7	......
1920	4.5	8.4	13.9	8.1	8.4	2.4	4.2	8.5	7.8	33.8	......
1921	4.7	8.5	13.8	7.4	8.7	2.1	3.9	7.9	7.3	35.6	......
1922	5.0	5.9	10.5	8.5	9.3	3.0	3.5	8.6	9.0	36.6	......
1923	4.6	5.4	9.4	8.5	8.7	3.2	3.9	8.3	8.8	39.0	......
1924	5.0	6.0	7.6	7.6	7.4	2.5	4.0	7.7	9.6	42.7	......
1925	4.5	5.9	8.0	7.8	7.7	2.6	4.2	8.3	11.6	39.3	......
1926	4.3	5.8	8.6	7.9	8.2	2.5	4.3	8.2	10.2	40.0	......
1927	4.4	6.1	8.6	8.2	8.5	2.4	3.9	7.7	9.1	41.0	......
1928	4.3	5.3	8.4	8.1	9.0	2.5	4.5	8.2	9.6	40.1	......

COMPUTED YIELD INDICES
(See column 11, Table 1)

TABLE 3

Year	North Carolina	South Carolina	Georgia	Alabama	Mississippi	Tennessee	Louisiana	Arkansas	Oklahoma	Texas	Average
1909	226	211	172	156	174	168	------	159	136	133	160
1910	222	211	165	159	173	162	------	176	200	156	172
1911	311	244	219	190	179	218	------	204	161	167	196
1912	254	226	170	175	157	192	------	188	181	196	190
1913	254	215	211	181	159	210	------	214	109	142	173
1914	302	250	229	200	201	227	170	190	198	179	204
1915	285	248	201	143	173	180	160	186	211	164	185
1916	228	162	178	84	141	191	158	185	145	130	148
1917	207	213	176	138	192	158	203	179	180	140	169
1918	267	228	184	166	193	197	157	159	132	124	165
1919	265	196	126	109	158	182	110	168	187	162	160
1920	259	235	123	110	123	185	145	167	196	166	164
1921	282	161	102	131	168	216	121	152	104	105	132
1922	215	122	95	129	150	186	123	166	115	123	133
1923	263	185	93	100	106	129	132	132	115	149	137
1924	206	168	150	164	212	142	170	160	157	142	158
1925	282	165	188	201	260	207	240	218	164	122	173
1926	294	217	189	172	220	196	195	202	163	151	180
1927	236	146	157	172	192	183	137	141	139	118	145
1928	194	185	141	144	168	176	164	162	137	143	152

NOTE.—Average obtained by weighting on basis of percentages in Table 2 (a).

TABLE 4

Year	1	2	3	4	Year	1	2	3	4
1909	29,667	160	9,930	9,641	1921	30,144	132	8,324	7,768
1910	31,029	172	11,165	11,219	1922	32,453	133	9,030	9,467
1911	34,428	196	14,117	15,081	1923	36,264	137	10,394	9,781
1912	32,971	190	13,106	13,183	1924	40,233	158	13,290	13,119
1913	35,484	173	12,843	13,531	1925	44,837	173	16,228	15,382
1914	36,354	204	15,515	15,883	1926	45,963	180	17,308	17,332
1915	31,035	185	12,011	11,044	1927	39,455	145	11,969	12,533
1916	34,542	148	10,695	11,262	1928	44,249	152	14,071	13,856
1917	33,203	169	11,739	11,101					
1918	35,457	165	12,239	11,796	Sum	716,058	3,296	247,136	247,305
1919	33,094	160	11,077	11,197	Mean	35,803	165	12,357	12,365
1920	35,196	164	12,076	13,129					

Column 1.—Total acreage for 10 States. (000 omitted. See final column Table 2.)
Column 2.—Computed average yield per acre for 10 States. (See final column, Table 3.)
Column 3.—Computed production for 10 States, in 500-pound gross weight bales (478 pounds net — 000 omitted).
Column 4.—Production for 10 States, in 500-pound gross weight bales (000 omitted).

NOTE.—The correlation coefficient between columns 3 and 4 (computed production for the 10 States and actual production) is +0.97.

Table 1 contains the basic data used in all computations for the States of North Carolina, South Carolina, Georgia, Alabama, Mississippi, Tennessee, Louisiana, Arkansas, Oklahoma, and Texas. Column 1 of the table shows the per-acre yield of cotton for the 10 respective States as reported by the Department of Agriculture. Column 2 contains the weevil indices, expressed in percentages of reduction in yield, as similarly reported; these represent the estimated percentage reduction by weevil from a full yield of cotton. Column 3, shows an adjusted yield, or the approximate yield that would have obtained without weevil damage, and, obviously, are data directly related to the varying weather from year to year. They are obtained by the equation $\overline{Y}=\frac{y}{1-w}$, where "$\overline{Y}$" is the adjusted yield (column 3), "y" the yield (column 1) and "w" the weevil indices in percentages of yield reduction (column 2). These data are the best indications obtainable of what the yield would have been from year to year without loss from weevil. Columns 4 to 9 contain the various weather data used in the correlations for the several States, as indicated hereinafter for each. Column 10 shows the computed adjusted yield indices determined by multiple correlations and regression equations based on the relation of the weather data to the adjusted yields in column 3. The adjusted yields are used as the basic yield data because of their direct relation to the weather conditions with weevil damage eliminated. Column 11 shows the final computed yield indices for the respective States, obtained by the equation $\overline{Y}=y-yw$ where "$\overline{Y}$" is the computed yield (column 11); "y" the computed adjusted yield (column 10), and "w" the percentage weevil data (column 2).

Next, we reduce the final computed yield indices (column 11 Table 1; also Table 3) for the several States, to a unit or average per-acre yield for the entire area of 10 States, by weighting on an acreage-percentage basis. That is, we determine the percentage of the total acreage for all States that is represented by the acreage of the individual States, and apply these to the respective computed acreage yield indices, shown in column 10 of Table 1, and in Table 3.

Table 2 shows the acreage (000 omitted) of cotton harvested for the several States, for each of the 20 years, while Table 2a gives the percentage of the total accounted for by each State, as explained in the preceding paragraph. Table 3 contains a tabulation of the computed per-acre

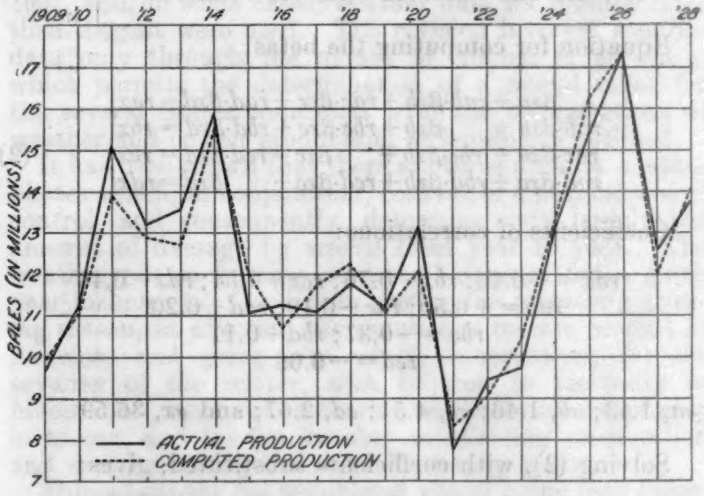

FIGURE 1.—Showing graphic relation between the production of cotton in the 10 principal producing States and the computed production from weather records—production in bales of 500 pounds, gross weight

yield indices, shown in column 11 of Table 1, for the respective States, the final column giving the average computed per-acre yield for the entire area, obtained by weighting on the percentage basis as above.

Finally, Table 4 shows, in column 1, the total acreage for the 10 States for each of the 20 years; column 2, the computed average yield per acre (final column in Table 3); column 3, the computed 500-pound gross weight bales (478 pounds net), and column 4 the total production in bales for the 10 States. The correlation coefficient between columns 3 and 4, or the computed production and actual production, is +0.97. A graphic relation is shown in Figure 1.

THE WEATHER DATA AND COMPUTATIONS

The weather data used, as hereinafter indicated for the several States, are monthly rainfall, number of rainy days, monthly mean temperature, percentage of sunshine, post meridian relative humidity, mean maximum temperature, mean minimum temperature, and the average daily range of temperature. For the rainfall data, number of rainy days, and monthly mean tempera-

ture, records for all stations of the Weather Bureau maintained in the respective States were included, about 600 in all, and for sunshine, post meridian relative humidity, maximum and minimum temperatures, and daily temperature range, those for first-order stations within and on the border of the respective States were generally used, as later indicated. The relative humidity data are the monthly means of the observations made at 8 p. m., seventy-fifth meridian time, which corresponds to 7 p. m. local time in most of the Cotton Belt. The sunshine data are the mean monthly percentages of the possible amount.

Details for the several States are as follows:

North Carolina.—The weather data used are: (*a*) May rainfall; (*b*) June rainfall; (*c*) July sunshine; and (*d*) September rainfall. The first-order station data are the means for Charlotte, Raleigh, and Wilmington, N. C., and Norfolk, Va. The details of computations for North Carolina are shown in the following equations; those for the other States are similar:

The correlations and regressions for North Carolina:

$$R^2 = \beta xa \cdot rax + \beta xb \cdot rbx + \beta xc \cdot rcx + \beta xd \cdot rdx \tag{1}$$

Equation for computing the betas:

$$\left.\begin{array}{l} \beta xa + rab\cdot\beta xb + rac\cdot\beta xc + rad\cdot\beta xd = rax \\ rab\cdot\beta xa + \beta xb + rbc\cdot\beta xc + rbd\cdot\beta xd = rbx \\ rac\cdot\beta xa + rbc\cdot\beta xb + \beta xc + rcd\cdot\beta xd = rcx \\ rad\cdot\beta xa + rbd\cdot\beta xb + rcd\cdot\beta xc + \beta xd = rdx \end{array}\right\} \tag{2}$$

Coefficients of correlations:

$$\begin{array}{c} rax = -0.46;\ rbx - 0.76;\ rcx + 0.54;\ rdx - 0.46 \\ rab = +0.50;\ rac - 0.19;\ rad + 0.20 \\ rbc = -0.37;\ rbd + 0.11 \\ rcd = -0.08 \end{array}$$

σa, 1.43; σb, 1.46; σc, 4.51; σd, 2.67; and σx, 36.59

Solving (2), with coefficients substituted, gives:

$$\beta xa - 0.034;\ \beta xb - 0.598;\ \beta xc + 0.283;\ \beta xd - 0.365$$

The regression equation:

$$\begin{aligned} \overline{X} = M_X + \beta xa\frac{\sigma x}{\sigma a}(A - M_A) + \beta xb\frac{\sigma x}{\sigma b}(B - M_B) \\ + \beta xc\frac{\sigma x}{\sigma c}(C - M_C) + \beta xd\frac{\sigma x}{\sigma d}(D - M_D) \end{aligned} \tag{3}$$

Where $\overline{X}$ is the North Carolina computed, adjusted per-acre yield indices; X, the adjusted per-acre yield of cotton. (Table 1, column 3.) A, B, C, and D the respective weather data, and M_A, M_B, M_C, and M_D their means; all as shown in Table 1.

Substituting the proper data in Table 1 and those obtained from equation 2 and solving 3, gives the following.

$$\overline{X} = -0.87A - 14.99B + 2.30C - 5.00D + 210.3 \tag{4}$$

South Carolina.—The weather data used are: (*a*) Number of rainy days in June: (*b*) July rainfall; and (*c*) August post meridian relative humidity.

First-order station data for Augusta, Ga., Charlotte, N. C., and Charleston, Columbia, and Greenville, S. C. The correlation coefficients are, $rax - 0.43$; $rbx - 0.43$; and $rcx + 0.41$, with intercoefficients, $rab + 0.23$; $rac +$ 0.06; and $rbc + 0.14$. The standard deviations are, a, 2.20; b, 2.42; c, 4.77; and x, 34.72. The betas, a, -0.364; b, -0.415; and c, $+$ 0.490. The constants, $-5.74A$; $-5.96B$; $+3.57C$; $+48.4$.

Georgia.—The weather data used are: (*a*) May mean maximum temperature; (*b*) June mean daily temperature range; and (*c*), total rainfall May to July, inclusive. First-order station data for Atlanta, Augusta, Macon and Thomasville. The correlation coefficients, $rax +$ 0.49; $rbx + 0.69$; $rcx - 0.61$, with intercoefficients, $rab +$ 0.27; $rac - 0.05$; $rbc - 0.71$. The standard deviations, a, 2.46; b, 1.52; c, 3.51, and x, 25.87. The betas, a, $+0.381$; b, $+0.338$; and c, $+0.352$. The constants, $+4.01A$; $+5.75B$; $-2.59C$; -218.5.

Alabama.—The weather data used are: (*a*) April mean temperature; (*b*) May rainfall; (*c*) June sunshine; and (*d*) July rainfall. First-order station data for Chattanooga, Tenn., Birmingham and Mobile, Ala., and Meridian, Miss. The correlation coefficients, $rax +$ 0.37; $rbx - 0.57$; $rcx + 0.40$; $rdx - 0.60$, with intercoefficients, $rab + 0.03$; $rac \pm 0.00$; $rad - 0.24$; $rbc - 0.33$; $rbd +$ 0.06; $rcd - 0.10$. The standard deviations, a, 2.15; b, 1.90; c, 7.75; d, 2.67, and x, 26.17. The betas, a, $+0.268$; b, -0.486; c, $+0.191$; and d, -0.488. The constants, $+3.26A$; $-6.69B$; $+0.65C$; $-4.78D$; -18.6.

Mississippi.—The weather data used are: (*a*) April rainfall; (*b*) May rainfall; (*c*) June rainfall; and (*d*) July mean temperature. All data are State means. The correlation coefficients, $rax - 0.45$; $rbx - 0.47$; $rcx - 0.49$; $rdx + 0.44$, with intercoefficients $rab - 0.08$; $rac + 0.33$; $rad - 0.25$; $rbc + 0.43$; $rbd - 0.08$; $rcd - 0.15$. The standard deviations, a, 2.72; b, 2.39; c, 1.67; d, 1.01; and x, 38.43. The betas, a, -0.359; b, -0.407; c, -0.152; and d, $+0.295$. The constants, $-5.07A$; $-6.54B$; $-3.50C$; $+11.22D$; -616.4.

Tennessee.—The weather data used are: (*a*) May rainfall; (*b*) May mean minimum temperature; (*c*) June mean minimum temperature; and (*d*) July mean temperature. First-order station data for Cairo, Ill., and Memphis and Nashville, Tenn. The correlation coefficients, $rax - 0.52$; $rbx + 0.41$; $rcx + 0.36$; and $rdx + 0.38$, with intercoefficients, $rab - 0.09$; $rac - 0.35$; $rad - 0.23$; $rbc + 0.05$; $rbd - 0.01$; $rcd + 0.29$. Standard deviations, a, 1.45; b, 2.73; c, 2.45; d, 1.42; and x, 31.73. The betas, a, -0.381; b, $+0.372$; c, $+0.133$; and d, $+0.257$. The constants, $-8.34A$; $+4.32B$; $+1.72C$, $+5.74D$; -591.9.

Louisiana.—The weather data used are: (*a*) Rainfall for April and May combined; (*b*) June sunshine; (*c*) June mean daily temperature range; and (*d*) July mean minimum temperature. First-order station data New Orleans and Vicksburg for sunshine, and Alexandria, Minden, and Monroe for daily temperature range and mean minimum temperature; for rainfall the State means were used. Shreveport was not used for sunshine data because these are not readily available for that station, while the records for Alexandria, Minden, and Monroe were employed in the case of temperature, because these stations represent the cotton-growing sections of Louisiana better than do Vicksburg and New Orleans; sunshine data are not available for Alexandria, Minden, and Monroe. In the case of Louisiana, only 15 years record, from 1914 to 1928, inclusive, were used, because the available early weevil data for that State appear out of harmony with other States, and also with weather records, especially for the years 1909 and 1910 for which the estimated weevil damage is reported as 42 and 40 per cent, respectively, with the next highest figures 14 per cent for Texas and 15 per cent for Mississippi.

The correlation coefficients for Louisiana are: $rax-0.63$; $rbx+0.64$; $rcx+0.59$; $rdx+0.53$, with intercoefficients, $rab-0.58$; $rac-0.63$; $rad-0.41$; $rbc+0.52$; $rbd+0.09$; $rcd+0.10$. The standard deviations, a, 2.83; b, 6.22; c, 1.50; d, 1.58; and x, 33.19. The betas, a, $+0.026$; b, $+0.441$; c, $+0.330$; and d, $+0.468$. The constants, $+0.305A$; $+2.35B$; $+7.30C$; $+9.83D$; -801.3.

Arkansas.—The weather data used are: (*a*) Number of rainy days in April; (*b*) May rainfall; (*c*) number of rainy days in June; and (*d*) July post meridian relative humidity. First-order station data for Fort Smith and Little Rock, Ark., Memphis, Tenn., and Shreveport, La. Correlation coefficients, $rax-0.30$; $rbx-0.46$; $rcx-0.36$; and $rdx+0.36$; with intercoefficients, $rab+0.05$; $rac+0.19$; $rad+0.17$; $rbc+0.31$; $rbd+0.11$; $rcd+0.07$. The standard deviations, a, 1.99; b, 2.07; c, 2.61; d, 5.23; and x, 24.06. The betas, a, -0.322; b, -0.435; c, -0.197; and d, $+0.476$. The constants, $-3.90A$; $-5.05B$; $-1.82C$; $+2.19D$; $+131.4$.

Oklahoma.—The weather data used are: (*a*) Mean daily temperature range in May; (*b*) mean temperature for June and July, combined; and (*c*) post meridian relative humidity for August. First-order station data for Oklahoma City, Okla., Amarillo, Tex., and Fort Smith, Ark. The correlation coefficients, $rax-0.33$; $rbx-0.33$; and $rcx+0.78$, with intercoefficients, $rab-0.07$; $rac-0.21$; $rbc-0.41$. The standard deviations, a, 1.55; b, 1.78; c, 7.74; and x, 34.99. The betas, a, -0.181; b, -0.047; c, $+0.723$. The constants, $-4.09A$; $-0.92B$; $+3.27C$; $+167.8$.

Texas.—The weather data used are: (*a*) Rainfall, December to March, inclusive; (*b*) April mean maximum temperature; (*c*) May rainfall; (*d*) June mean minimum temperature; (*e*) July post meridian relative humidity; and (*f*) mean daily temperature range in August. Texas is the only State in which antecedent rainfall shows a significant relation to the yield of cotton. First-order station data are for Abilene, Amarillo, Fort Worth, Galveston, Palestine, San Antonio, Tex., and Shreveport, La. The correlation coefficients, $rax+0.51$; $rbx-0.36$; $rcx+0.35$; $rdx-0.41$; $rex+0.42$; $rfx-0.65$, with intercoefficients, $rab-0.17$; $rac+0.24$; $rad-0.27$; $rae+0.35$; $raf-0.11$; $rbc-0.20$; $rbd+0.16$; $rbe-0.35$; $rbf+0.16$; $rcd+0.04$; $rce+0.09$; $rcf-0.57$; $rde-0.39$; $rdf+0.12$; $ref-0.18$. The standard deviations, a, 2.56; b, 2.14; c, 1.44; d, 1.75; e, 4.57; f, 1.32; and x, 25.10. The betas, a, $+0.372$; b, -0.174; c, -0.120; d, -0.180; $e+0.057$; and f, -0.618. The constants, $+3.65A$; $-2.04B$; $-2.09C$; $-2.58D$; $+0.31E$; $-11.75F$; $+701.7$.

In Texas, there was found, after the usual adjustment of yield on the basis of weevil damage, a very definite diminishing trend in per-acre yield, due, most likely, to the marked expansion in acreage westward and northwestward in sections less productive from a per-acre-yield standpoint. Before applying the correlations of weather data to the adjusted yields, as in the other cases, it was found necessary to include this trend in the adjustment, and, therefore the data in column 3, Table 1, for this State, were obtained by first adjusting the yield for weevil as in the other cases, then for trend in the usual way for trend elimination. The trend was found to be -1.34; that is an average yearly decrease in per-acre yield by this amount, and the accumulations were added for the respective years of the series. The accumulated amounts for the trend adjustments were as follows: 1909—1 pound per acre; 1910—3; 1911—4; 1912—5; 1913—7; 1914—8; 1915—9; 1916—11; 1917—12; 1918—13; 1919—15; 1920—16; 1921—17; 1922—19; 1923—20; 1924—21; 1925—23; 1926—24; 1927—25; and 1928—27. The computed, adjusted yields for Texas, column 10, Table 1, for the several years, include these trend values and they are, therefore, deducted before and in addition to the weevil adjustment to obtain the finally computed yield in column 11. Apparently this 20-year period covers the trend tendency and, consequently, in applying the data to future years the last figure, that is, 27 pounds per acre, may be considered a constant.

THE WEATHER-WEEVIL INDICES

Reference has been made to a paper published in the MONTHLY WEATHER REVIEW in August, 1928, entitled "Weather and the Cotton Boll Weevil," and to the fact that this study was the first step in the present investigation, and forms a part of it. It has been found desirable, however, to revise that paper in certain respects, so that advantage could be taken of the data that have become available since its preparation, and also to make the time element comparable, in all cases, to the period of the growing season covered by the subsequent study, as before outlined. The former records ended with 1927, and, in some cases, weather data for months later than August were used. The revision involves weather data only through the month of August in all cases, which permits the determination of a weevil index for the several States coincident with the computations of weather and cotton production, as heretofore outlined.

It has been shown that there are three distinct weather phases which, in conjunction, constitute a natural weevil control, and consequently, determine very largely the amount of damage by weevil from year to year. The weather phases bearing on weevil damage for a given year include: (*a*) Conditions during the preceding growing season, as affecting the number of insects present at its close and going into winter hibernation; (*b*) the severity of the winter, with relation to mortality in hibernation, which has a bearing on the number emerging in spring; and (*c*) the weather as affecting propagation and activity during the current growing season.

The indices for the number of weevil going into hibernation were originally computed from the preceding growing season's weather, but in the revision the percentage of damage done by weevil during the preceding summer has been substituted. Evidently, the amount of weevil damage must have a very definite relation to the number present, and this affords a much simpler and very convenient index for the first phase of the problem. For the second phase—index for deaths in hibernation—records of the lowest temperature reached during the winter, as in the original paper, have been retained; and also the prevailing weather during the growing season for the final phase, but with some slight modifications to afford synchronization, as before indicated. In addition to the above, regression constants have been established for computing weevil indices for the States of North Carolina, South Carolina, and Tennessee, not included in the original paper. These latter, because of the comparatively few years of weevil presence, are naturally less dependable than for those States with longer periods of weevil activity.

For the revised weevil index determinations, the following data were used for each of the 10 States: (*a*) The percentage of damage by weevil, for the preceding year (see column 2, Table 1); (*b*) minimum temperature during the preceding winter, represented by the average of the lowest recorded during the winter at first-order

stations within or near the border of the respective States, as indicated below; and (c) the growing season weather data, as hereafter named, for the respective States. For phase (c), data relating to rainfall, number of cloudy days and number of rainy days are respective State means for all Weather Bureau stations maintained in the respective States, while the sunshine and relative humidity data are for the first-order stations named for each State. The relative humidity data are the means for the noon and post meridian observations. In the following summary the details of computations are omitted and only the constants applicable to the several phases for computing the weevil indices given:

DATA USED FOR REVISED WEATHER-WEEVIL COMPUTATION

(The a and b phases are the same for all States, as before indicated)

North Carolina.—Weather data (c) percentage of possible sunshine, June to August, inclusive. First-order stations Charlotte, Raleigh, and Wilmington, N. C., and Norfolk, Va. The constants, $+0.25b$; $-1.53c$; $+10.9$. (Phase "a" not used, because of shortness of record.)

South Carolina.—Weather data (c) percentage of possible sunshine, July and August, combined. First-order stations Charleston, Columbia, and Greenville, S. C., Augusta, Ga., and Charlotte, N. C. The constants, $+0.20a$; $+0.67b$; $-1.41c$; $+99.0$.

Georgia.—Weather data (c) relative humidity July and August, combined. First-order stations Atlanta, Augusta, Macon, and Thomasville, Ga. The constants, $+0.44a$; $+1.35b$; $+1.88c$; -132.9.

Alabama.—Weather data (c) relative humidity, July and August, combined, and (c_1) August rainfall. First-order stations, Birmingham and Montgomery, Ala., and Meridian, Miss. The constants, $+0.46a$; $+0.57b$; $+0.99c$; $+1.28c_1$; -66.1.

Mississippi.—Weather data (c) number of cloudy days, April to August, inclusive; (c_1) relative humidity, July and August, combined. First-order stations Meridian and Vicksburg, Miss., and Memphis, Tenn. The constants, $+0.24a$; $+0.51b$; $+0.38c$; $+0.75c_1$; -52.4.

Tennessee.—Weather data (c) rainfall July and August, combined. First-order stations Memphis and Nashville, Tenn., and Cairo, Ill. The constants, $+0.52a$; $+0.62b$; $+0.88c$; -41.1.

Louisiana.—Weather data (c) rainfall June and July, combined; (c_1) relative humidity, June to August, inclusive. First-order stations Shreveport, La., and Vicksburg, Miss. The constants, $+0.30a$; $+0.19b$; $+1.14c$; $+0.39c_1$; -27.3.

Arkansas.—Weather data (c) number of rainy days, June and July, combined. First-order stations Fort Smith and Little Rock, Ark., and Memphis, Tenn. The constants, $+0.43a$; $+0.40b$; $+1.27c$; -16.5.

Oklahoma.—Weather data (c) rainfall, June and July, combined. First-order stations Oklahoma City, Okla., and Fort Smith, Ark. The constants, $+0.32a$; $+0.63b$; $+4.48c$; -25.2.

Texas.—Weather data (c) rainfall, June and July combined; (c_1) relative humidity, June to August, inclusive. First-order stations Abilene, Amarillo, Fort Worth, Palestine, San Antonio, and Taylor, Tex., and Shreveport, La. The constants, $+0.31a$; $+0.75b$; $+1.19c$; $+0.32c_1$; -23.8.

CONCLUSIONS

In the matter of application of the results of this study to future years for an early indication of cotton production, it may be pointed out that practically all data are available soon after the close of August for a current growing season. The compilations in full, including the combined weather-weevil determinations, and the weather-yield correlations for the 10 States, comprise some 75 independent variants, covered into the final results through 20 separate equations, but only 1 contains more than 4 variants. None of the data, except September rainfall in North Carolina, extends later in the season than August.

In case application of results is desired before the North Carolina September rainfall becomes available, this may be approximated by using the average rainfall for that month. In such case, because of the large number of variants used, the error would be negligible, as a rule. For example, by using the North Carolina average September rainfall, instead of the actual, for the 20-year period covered by this study, the results would differ from those obtained by using the actual rainfall by an average of less than 0.3 of 1 per cent, with a maximum difference of only 1 per cent, notwithstanding September rainfall in North Carolina varied during the period from 1.2 inches to 11.2 inches. This is a striking indication that the methods used in these computations give a stability in results much greater than is usually found in weather-crop correlation work, which inspires confidence as to its satisfactory future application.

Acknowledgment is hereby made of the valuable cooperation given in this study by Mr. W. A. Mattice, who assisted in computing the many correlations required, and by Miss G. B. Diehl, in compilation and computation of necessary data.

METEOROLOGY AND ITS IMPORTANCE TO AVIATION

By W. J. HUMPHREYS

Some knowledge of the air and its ways obviously is essential to both the science and the art of aerial navigation. It does not follow, however, that all who are concerned with this science and this art need to know exactly the same things about the atmosphere, nor to know them in exactly the same way. The designer of the engine must know the composition and density of the atmosphere at all levels at which the machine is supposed to operate, since these are essential factors in the determination of the power available, but he does not need to know much about the theory of turbulence, skin friction, stream lines, and the like. These vitally important matters concern, most of all, the designers of the wings and the fuselage. Finally the aviator, though his very life depends on somebody's knowledge of these things, does not often himself bother about them. He would be bored beyond endurance by the exact observations, experiments, "high-brow" theories, and tedious calculations they require. His is the active, impatient spirit that wants to be up and flying. He would rather fly a "barn door" right away than hang around a month or two waiting for the finest product the laboratories can produce. Neither does he care to know, nor much need to know, the technical terms and long equations which the meteorologist uses in his discussions of wind and weather. He takes his machine,

engine, wings and all, as prepared by others, and he wants the prediction of the weather the same way—handed to him on a platter, as it were. And in the main his wishes are entirely reasonable. Nevertheless, while in the air and on making a forced landing the aviator has to be very much "on his own," as we say. At such times a working knowledge of the machine and a practical understanding of the atmosphere are essential to his success.

But to be specific; exactly what knowledge of meteorology does the aviator really need, when there is a specialist at every airport to tell him what the weather is along the route he is about to take, and what it is expected to be at every mile of the way? Well, he needs at least enough knowledge of meteorology to enable him to read a weather map understandingly; enough to enable him to discuss this map intelligibly with the man who makes the forecasts for him; enough to enable him to judge, while in the air, whether or not the forecasts are coming true; and enough to give him an understanding of the weather significance of the clouds and the look of the sky. From his study, with the aid of the forecaster, of the latest weather map, constructed from extremely recent observations along and on either side of the route to be flown, he learns what sort of weather to expect at each particular place and time. But weather does not always come exactly according to the forecast. It therefore is essential that the aviator know not only what kind of weather he probably will encounter, and where, but also he must definitely understand the significance of the clouds and other weather appearances and their relations to the anticipated weather. He must know to a certainty from the looks of things whether the expected storm, for instance, is developing sooner than anticipated, or later. In short, in addition to being able to consult intelligently with the station meteorologist and read knowingly the weather map, he must be able to visualize that map in terms of actual weather phenomena, and especially must he become weatherwise for the route he is flying, just as the fisherman is weatherwise in respect to his own home waters.

The station meteorologist must know all the aviator does about the atmosphere and a good deal besides. He must be an expert short range—three to six hours—forecaster for his region. He also should have at least a working knowledge of theoretical meteorology, including, of course, the physical processes involved. This additional knowledge will not only make him a better forecaster but likewise increase his value as a consultant.

In addition to the above there also are a number of facts about the atmosphere the aviator should know. The station meteorologist should know them, too, in fact he should know nearly all that is known about meteorology, or, at least, have at hand the best books on the subject—English, French, and German, including the mathematics and physics—and know how to look up at a moment's notice anything that is in them. But to return to what the aviator should know.

STRUCTURE OF THE ATMOSPHERE

He should know that the atmosphere has structure, both general and detailed. He should know, for instance, that from the surface of the earth up to the height of 6 or 7 miles, in middle latitudes, the temperature decreases at the average rate of about 1° F. for each 300 feet increase of level, though near the surface the the rate varies widely and often is even reversed, as will be explained presently. This extensive portion of the atmosphere is called the troposphere; that is, the turning-over or convectional region. This is the region of turbulence and eddies, especially near the ground, of vertical convection, of clouds and of storms. Above it in that region we call the stratosphere—the aviator's paradise, if his machine were adapted to it—there is no appreciable turbulence of any kind, and never a cloud to smore the sun, blink the stars, or drag him down with a load of ice. In many respects this serene stratum of the atmosphere is ideal for long flights in high latitudes.

Of course, though, no matter how long one might be able to fly at this great height he must have started from the ground and eventually must come back to the ground, and in so doing pass through the surface layer that so frequently is turbulent. Usually this turbulence means nothing worse than a few bumps that may remind one of riding over cobblestones; but occasionally it means a great deal more, especially to the beginner and the incautious, for the eddies that make these bumps have also caused many a disastrous side slip when the turning was sharp and the banking steep. The method of prevention is obvious—don't be in such a hurry, take a wide curve and bank gently until a considerable height has been attained.

Not only must the aviator take off from the surface and land on the surface, but his place of landing is not always an airport, properly located and fully equipped. In all such cases it is well to avoid, after sundown, the lower end of any steep valley or canyon, especially if it happens to be treeless and covered with snow. This is because cold surface air (and where there is no general wind the surface air gets much colder after sundown than does the air some distance above) drains away to lower levels, and under favorable circumstances, such as those just mentioned, frequently develops into a veritable torrent.

And there is one more place the prudent aviator will shun—the heart of the thunderstorm. In it there are two dangers, the danger of being struck by lightning and the greater danger of being wrecked by violent winds. Some aviators emulate Tam O'Shanter by not minding the storm a whistle, but it should be recalled that on that memorable night Tam was gloriously drunk.

SOARING

The sport of soaring is now in the air, literally and figuratively. Soaring is tobogganing down an upflowing wind just as surf riding is tobogganing down the front and rising side of a traveling wave. Supporting breezes are above the crest and on the windward side of every hill and mountain, beneath the forward portion of the cumulus cloud, and even over the waves of the ocean, as the matchless albatross unwittingly reveals. But except in the case of the cumulus cloud these supporting currents are rather shallow, and dependent entirely on the direction and intensity of the surface winds. To this branch of aviation therefore an understanding of the air and its ways is not only helpful, as it is to all kinds of aerial navigation, but absolutely essential.

CEILING AND VISIBILITY IN THE UNITED STATES

NORTHEASTERN STATES

By C. G. Andrus

[Weather Bureau Airport, Cleveland, Ohio]

In the northeastern portion of the United States a well-defined excess of cloudiness and low ceiling is found along the shores of the Great Lakes and southeastward over a large portion of the inland areas. Much of the region is mountainous, which is conducive to further cloud formation by mechanical raising of moving air masses. Bounded on one side by the Great Lakes, on the other by the Atlantic Ocean, much of this area has high humidity. Clouds form quickly and easily and they frequently persist for several days, with ceilings which are little more than 500 feet above average ground elevations.

Between the two sources of moisture lie the Applachian ridges, which are frequently clouded, while areas on either side are almost clear. Such clouds are, of course, low, with ceilings dangerously near the mountain tops. The best average ceilings occur on the eastern flanks of the Blue Ridge where descending air is found with the prevailing westerly winds.

Besides the topography which tends to produce an abundance of low-ceiling weather, the drift toward the St. Lawrence valley of all LOWS and their attendant areas of condensation is a favoring factor in producing low ceilings. The average LOW has a low ceiling area around either its warm or cold front; sometimes along both.

Generally, high-pressure conditions are least likely to be accompanied by low ceiling, although one well defined exception is the HIGH which stagnates with its center over the mouth of the St. Lawrence. Other high-pressure conditions which result in low clouds are those of midwinter when cold air drifts across the warmer water over the Great Lakes.

A seasonal variation in low-ceiling conditions is well marked, especially in the Appalachian mountain regions and along the Great Lakes where the warmer seasons experience less and the colder more occurrences of low ceilings. Summer is as usual less subject to periods of low ceilings than is winter, over the whole area.

Low ceiling is especially important to air transport lines that operate across mountains because its presence may preclude flying over these mountains. Numerous cities, each with its encircling zone of air polluted by the products of combustion and manufacturing intensify the low-ceiling hazard at the airports in their vicinity and air pollution is therefore relatively higher in this section of the country than in any other.

Low ceiling in this area is dangerous in winter also because of its relation to ice accumulation on the planes, since it increases to a high degree the hazard involved in flying in the clouds. The low ceilings which attend line squalls and are sometimes obscured by violent rain and snowfalls have taken toll of several unwarned or unheeding pilots.

Use of dew-point data and careful study of their relation to the formation of low clouds are recommended as aids in predicting changes in ceiling. A rising dew point when the interval is small between it and the dry temperature is a fairly reliable indication of lowering cloud masses, on the warmer sides of LOWS.

Two peculiarities which occur occasionally are worth noting because of their danger. One is the tendency for two slightly separated horizontal cloud sheets to merge into one on the flanks of mountains. A pilot proceeding mountainward between the layers suddenly finds himself "pinched in." Mechanically induced vertical flow in the atmosphere near the mountains is the cause of this condition. The other peculiarity is the production of a fairly low ceiling by rain falling from clouds which may be more than several hundred feet high, sometimes in the alto-cumulus levels. This lower overcast develops first as scattered and windblown low scud masses. These grow, if the rain continues and the ground is well soaked, until they attain solid formation of an additional sheet of cloud only a few hundred feet off the ground, with ragged and billowy lower edges.

Visibility.—Low visibility restricts flying operations more in the northeastern section of the country than in any other part of the United States. Several causes are involved which are highly developed or frequent in this quarter and are in general similar to the causes of low ceilings but also include many others, some man made, which do not reduce ceiling. Some of these are on the increase.

Water vapor as an obstruction to vision is well identified with high humidity in air masses which have come across the Great Lakes or the Atlantic Ocean. Masses which have come inland from a long run over the sea and are not too briskly moved by the wind are more likely to produce fogs of wide extent than are those which have come inland after a short passage over the ocean and are moving at moderate or higher velocities. Sunlight and wind as a general rule are the main preventives of fog and the strongest agents in its dispersion.

Visibility is reduced in this section by other sources which are more effective here than elsewhere because of their abundance. The pollution of the air by products of combustion and manufacturing is definitely high in this section, not merely in the immediate vicinity of the offending agents but for considerable areas around.

Thus, large cities as a rule are surrounded by areas of low visibility resulting from pollution. Industrial works of certain kinds discharge products which reduce visibility to less than 2 miles for a distance of 15 miles or more. The effect is direct and indirect. Directly, such a quantity of small particles is spread through the air that visibility is reduced. Indirectly these particles tend to assist in the suspension in the air of moisture particles which by themselves would present no great obstacle to vision. Oily or tarry substances hold moisture and resist the drying influence of sunshine, and as the products of combustion often consist of such substances this action commonly intensifies fogs. Hydroscopic chemicals are abundant in the vicinity of many manufacturing plants which discharge fumes into the air. Pollution is a growing factor, and measure toward its control and reduction are likely to be necessary in the near future.

Dust plays no great part in reducing visibility in this area. Drifting snow in windy weather during the winter is a cause for lowered visibility along the ground and results in a hazard to planes when landing, but is otherwise more apparent than real as a danger.

The worst obstruction to vision in the moisture class is fog. Fine rain is likewise a serious obstruction to vision. As a rule, with both moisture and other particles the finer the particles the worse the visibility. A heavy rain with large drops does not hinder vision nearly as much as does one-tenth the rainfall in the form of a

drizzle. The densest fogs are those in which the droplets of moisture are exceedingly tiny.

Fog in the northeastern quarter of the country generally may be described as (1) valley, (2) mountain, (3) ocean, (4) snow or rain. Fog can frequently be ascribed to two or more of these conditions; often their origin and cause are more or less obscure because it is difficult to secure full information as to their exact extent.

Valley fogs are essentially phenomena due to radiation and air drainage. Their formation is best watched by assuming that they will form, unless inimical conditions are present, in any broad valley during the night hours. The longer the night the greater the chance and extent of fog. There is little chance for fog if at sunset the temperature and dew point have a difference of 15° F. or more. Such fogs may fill the valleys by sunrise but usually "burn off" under rising temperatures during the first four hours of daylight. If, however, a sheet of high clouds comes in over these fogs their dispersion is greatly delayed.

Mountain fogs are strictly low cloud ceilings which envelop the higher points of the terrain. When the ceiling lifts the fog observed as such by an observer on the mountain top disappears.

Ocean fogs occur on the coastal plain of the Atlantic seaboard and are frequenters of the southern and western sections of HIGHS which are located a short distance to the east of the Canadian and New England coasts. From local indications it is practicable to predict their occurrence by closely observing the wind direction and velocity and the temperature at stations on the coast. A desultory south or southeast wind whose temperature is normal or below in the daytime will often suddenly turn back to a chilly east or northeast light breeze at night and fog will attend this shift of wind. Once formed such fogs are persistent and depend for their dispersion on a greatly altered pressure distribution, as it often happens that an incoming LOW from the west will draw southerly to southwesterly winds up over the top of the fog for several hours before it gradually wears away the upper surface of the fog and draws out the colder inversional temperature layer of foggy air.

Fog in the vicinity of the Great Lakes is less common but similar in production to the ocean fogs. It is easily formed when precipitation has occurred or is still occurring with winds which are light to calm, if the temperature of the water surfaces is above that of the land. In winter the lakes have ice and their temperature is therefore near freezing. At other seasons lake temperatures are normally colder than land temperatures, and therefore, the fog is slow to develop over the land.

Any widespread fog is the result of a widespread condition, hence slower to disperse than a local or limited one. On the other hand, during the evening or the period of development all fogs are likely to start as local phenomena and if the night is long the merging of several local fogs may result by sunrise. A winter fog usually is less mobile and more likely to stagnate than a summer fog, while the spring fogs are involved in cold surfaces and are often abnormally stagnant.

"Snow" fogs result when warm, moist air blows over snow-covered terrain. The reduction of the air temperature by the snow is the cause. If the snow is substantial enough to last under the influence of the warm air fog will form. The farther to the windward the snow cover exists, the more likely is the fog to form at any specific point.

Rain in summer sometimes chills and wets the ground in a region to the extent that the lower strata of air are abnormally chilled while blowing very slowly over this region. Fog will result if the chilling is great or the moisture content of the air is high. Such fogs are usually transient, although if they occur in the early evening they may merge into valley fogs. Rising wind will disperse them quickly.

SOUTHEASTERN STATES

By JOHN A. RILEY

[Weather Bureau Airport, Atlanta, Ga.]

The southeastern portion of the United States lies south of the most frequented storm tracks. The storms that cause heavy rainfall in this region are southwestern LOWS, including those that form in the Gulf of Mexico and those from the northwest that move far to the south before recurving. A considerable portion of the West Indian hurricanes pass inland on the Gulf coast or move up the Atlantic coast, causing widespread cloudiness, high winds, and heavy precipitation. But these storms are confined mostly to late summer and autumn and, in most years, are not frequent enough seriously to affect flying.

This comparative freedom from storms, however, does not mean that the flying weather of the Southeast is better than that of other sections. In fact the topography of the region and the proximity of an abundant supply of heat and moisture from the Gulf of Mexico and the Atlantic combine to produce weather conditions that seriously interfere with flying at frequent intervals during a considerable part of the year.

The Appalachians, forming a high backbone between the Mississippi River and the Atlantic, are a decided topographic factor in determining ceiling and visibility. Even in fair weather a perpetual haze hangs over these mountains, as such names as Great Smoky and Blue Ridge suggest. This haze is sometimes so stratified as to resemble clouds, and the upper surface at 4,000 to 6,000 feet (1,200 to 1,800 meters) often furnishes a distinct horizon from above.

A notable instance of the effect of moist winds blowing across mountain ranges is found in northern Georgia and southwestern North Carolina. On the southern slope the rainfall increases from 50 and 55 inches (130 to 140 centimeters) over the lower slopes to 60 and even 80 inches (150 to 200 centimeters) a year on the higher slopes, while in the valleys beyond the rainfall drops to less than 40 inches (100 centimeters). The ridges of the southern Appalachians in Tennessee, Alabama, and Georgia seem to stretch out like fingers to grapple with the prevailing winds and squeeze out the moisture to form clouds, fog, and rainfall.

The Gulf of Mexico, as R. DeC. Ward points out,[1] is an important control of the climates east of the Rocky Mountains. It is a very warm body of water, and the most important source of moisture for the heavy rainfall of the Southeast.

The Atlantic probably exercises an equally important control over flying conditions on the Atlantic seaboard and as far west as the Blue Ridge Mountains, easterly winds being definitely associated with low stratus clouds which are the most serious handicap to flying in this region. At Atlanta, for instance, the percentage of rain during the time the wind is northeast is five times as high as with northwest winds. Taking this value as unity for northeast winds the relative probability of rain for the other directions is as follows: North, 0.31; northeast, 1; east, 0.56; southeast, 0.59; south, 0.32; southwest, 0.61; west, 0.26; northwest, 0.17.[2]

[1] The climates of the United States.

[2] Cf. The rain-bearing winds at Atlanta, Ga., by C. F. Von Herrmann, Monthly Weather Review, Nov., 1925.

High-pressure areas on the middle or north Atlantic coast constitute the controlling factor in the formation of low clouds over the east slope. A slow-moving HIGH over New England, with an extension southwestward, and a moderate LOW on the Gulf coast or in the Mississippi Valley may be depended upon to produce a more or less extended period of low overcast.

The normal clockwise movement of the winds around the northeastern HIGH causes the easterly surface winds to be overrun by moist southerly winds from the Gulf. The winds in this sytem, both at the surface and aloft, have a high vapor content and the relative humidity increases with falling temperature as the surface winds climb the slope from sea level, across the Piedmont Belt at 1,000 feet (300 meters) to 2,000 feet (600 meters) or more at the mountains. At the same time the southerly winds aloft are near the saturation point which may be passed as convergence causes further ascent and cooling.

The first clouds may form either near the ground or in the overrunning southerly winds, depending on the vertical distribution of temperature and humidity. When fully developed there may be four or five distinct cloud strata. Weather maps of February 7, 13, and 22, 1928, illustrate these conditions. Typical conditions occurred on September 13, 1929, when Air Mail Pilot Sid Molloy lost his life at Atlanta while attempting to fly underneath a very low overcast which touched the ground in places.

F. T. Cole, of the Weather Bureau Aerological Station at Due West, S. C., says that the most potent cause of low clouds from mid-November to mid-May is a strong LOW to the southwest with a good gradient. Lows that move to the north and east from the Gulf coast—Brownsville to Pensacola—bring low clouds about 12 hours ahead of the rain, and the rain is always accompanied by low clouds. But before low ceiling becomes a certainty the pressure must begin to fall; that is, the LOW must really begin to move. Lows that come out of the east Gulf, he says, will bring low clouds at all seasons of the year if of any intensity. Lows that pass up the Atlantic coast in the autumn, October 1 to December 15, frequently bring threatening weather that apparently moves in from the east. If the movement of the LOW is blocked low ceiling with easterly winds may prevail for several days, but the clouds will be broken and the rainfall light.

Cole finds that temperature and humidity are of little forecast value but that winds aloft are at times indicative of low clouds on the following day. A gradual change from east-southeast to south-southwest in a layer some 3,000 feet (900 meters) deep is almost a sure precursor of low ceiling and rain, but this does not hold true when the wind shifts abruptly.

A low overcast may occur when pressure gradients are insufficient to cause rainfall. Such conditions may prevail for several consecutive days and the weather then has a more or less regular diurnal sequence. Low clouds drift in between midnight and 3 a. m. or 4 a. m. and lift about 9 a. m. or 10 a. m. the following morning.

Moderately sharp temperature contrasts on the Jacksonville-Atlanta airway are often indicative of bad weather; they usually occur along the southeast margin of an incoming HIGH. The low temperature within the high-pressure area and the high temperature to the south and east produce the well-known displacement of the center of low pressure toward the colder region, usually toward the northwest.[3] As a result of this displacement the northerly surface winds are overrun by south and southwest winds, causing low clouds, rain, and poor visibility.

The period covered by the air-mail service in the southeast is too short to show the seasonal trends of flying weather. Ceiling measurements covering nine years at Due West, S. C., have been tabulated for this study by F. T. Cole. These figures show a steady decrease in frequency of low clouds from December to July, with a slight rise in August and September due to the hurricane season which reaches its height during this period, and then a drop to a minimum in October essentially the same as in July.

Low clouds are rather common on summer mornings but they seldom last all day; the duration of low clouds is much greater in winter. Considerable variation in frequency of bad flying conditions occurs from year to year in every month. For instance, February, 1929, was probably the worst month since regular schedules began in this district whereas February, 1930, was for the most part unusually fine.

Thunderstorms are the principal handicap to flying in summer; there are few warm days in summer when mail pilots in this territory do not report seeing one or more, and many times it is necessary to dodge one after another. It is not generally practicable to fly above them, but the pilot tries to pick out what appears to be the lightest or least active part of the storm.

Thunderstorms not only seriously reduce the ceiling and visibility while in progress, but the path of an afternoon or night thunderstorm is likely to be marked the following morning by ground fogs. On such nights temperature and dew-point readings are highly significant and are closely watched by experienced pilots. These fogs form within an hour or two after midnight and burn off soon after sunrise. Most of the inland fogs of summer are formed in this way; they are much more frequent than past records would indicate, for by 8 a. m., the time of the regular morning observation, summer fogs are entirely dissipated.

Over most of the Southeast, except lower Florida, dense fogs occur on an average of 15 to 20 or more days a year; the greatest frequency is in the valleys of the middle and southern Appalachians, diminishing toward the west as well as toward the Atlantic and Gulf coasts.

The more widespread and persistent fogs accompany weak cyclonic movements, and their cause is similar to that of low-stratus clouds previously discussed. Moist air transported by light southerly winds converging upon east and northeast winds from a HIGH to the northeast brings the temperature and dew point together to produce fog and perhaps misting rain. Such widespread fogs prevailed over much of the Mississippi Valley and the Southeast from December 8 to 15, 1929, with high pressure to the north and east and an indefinite low-pressure area from the lower Mississippi Valley to the north Pacific coast.

The course of rivers is often marked by morning fogs; at Memphis it has been observed that after a warm period a shift of the wind to a northerly or westerly direction is likely to bring fog over the city from the river. A considerable number of the winter fogs at Memphis do not begin until after 7 a. m., according to A. R. Long, Weather Bureau official at Memphis.

Coastal or marine fogs are most frequent where there are large temperature differences between the land and the water; they are therefore much less frequent along the Gulf and south Atlantic coasts than in New England. "Differences between land and water temperatures,"

[3] See MONTHLY WEATHER REVIEW Supplement No. 21, The preparation and significance of free-air pressure maps for the central and eastern United States, by C. L. Meisinger.

says Prof. H. C. Frankenfield, "are not so marked along the Atlantic and Gulf coasts as along the Great Lakes, and fogs forms with nearly equal temperatures when the latter do not differ sufficiently to cause complete condensation in the form of rain or snow. Frequently rain will be falling at one place on the coast while at the next station, only a short distance away, there will be dense fog. It is usually observed, however, that at the place where the rain is falling the wind velocity is greater than where the fog prevails and a decrease in the velocity would doubtless be at once followed by dense fog."

Frankenfield gives the following seasonal percentages of dense fog for the south Atlantic coast; Winter, 46; spring, 27; summer, 5; and autumn, 22. For the Gulf coast: Winter, 54; spring, 30; summer, 1; and autumn, 15.[4] Along the Gulf coast the maximum frequency of fog is from the northwest coast of Florida to the northeast coast of Texas, the number of foggy days increasing toward the west. The greatest frequency is in January; scarcely any occur from June to September.

Weather conditions are described as very favorable for aviation in Florida by A. W. Brooks, Weather Bureau official at Miami Airport, who states that during the first year of operations, air mail failed to leave Miami on schedule only once—September 28, 1929—when a hurricane was passing through the Florida Straits into the Gulf of Mexico. Dense fogs are rare in southern Florida and are mostly shallow ground fogs which quickly disappear after sunrise. A solid overcast of low stratus or nimbus clouds is rare in southern Florida, Brooks states, except during a passing shower or when a hurricane is in the vicinity.

CENTRAL STATES

By VINCENT JAKL

[Weather Bureau Airport, Fort Crook, Omaha, Nebr.]

The portion of the country considered in this section comprises those States or portions of States lying between about the eighty-eighth and one hundred and fifth meridians, and extending from the Canadian boundary to the southern limits of the country, but not including the immediate Gulf coast.

Over this area, in common with other portions of the country, the average conditions of ceiling and visibility can be judged to a fair degree of accuracy by the general average amounts of precipitation. Ceiling and visibility are both controlled in large measure by the amount of moisture—both visible and invisible—contained in the air, while the moisture element is in turn roughly proportional to the average frequency and intensity of precipitation. We therefore find that there is a progressive improvement with respect to these conditions from east to west, slow at first, and then more rapid westward from about the ninety-eighth meridian, as the more arid regions of the plains States are approached.

As regards visibility, another contributing factor to this graduation of average conditions from east to west is the general lessening in the amount of smoke from cities and industrial regions, parallel to the diminishing density of population westward. There is also an appreciable improvement in average visibility from north to south, this latitudinal difference being, however, confined to the colder months. As may be inferred, the Southern States enjoy a relative infrequency of snowfalls, as compared with Northern States, and snowfall, as is well known, diminishes visibility much more than rainfall. Moreover, the more pronounced changes in temperature and the precipitation that frequently attends such changes, which Northern States are subject to, are conducive to greater frequencies in light to moderate fogs. Dense fogs are brought about by special conditions, therefore we find that there is no important variation in this element with latitude, but a noticeable variation with longitude; that is, greater frequency in dense fogs over eastern than over western sections on the average. The more general use of natural gas for heating in the Southern States is perhaps not a negligible factor in bettering the conditions of visibility there as compared with Northern States.

The advantage that the Southern States enjoy is not really as great as might be apparent from the foregoing, as the favorable conditions mentioned are partly offset by low-pressure areas that first become evident as such in the Southwest and pass northeastward. These southwestern Lows develop with northeastward progress, and cause widespread precipitation attended by low clouds and poor visibility. In their pronounced form they are peculiar to the colder months, and affect the middle and much of the southern portions of this area.

The western portions of the area likewise are affected by a condition peculiar to them that modifies the general statement that visibility always improves westward. These are the dust and sand storms that affect the arid regions, more particularly those of the Southwest, and are most likely to occur in spring when the surface winds are on the average the strongest. The diminished visibility resulting from these storms is a factor to be reckoned with; nevertheless it is of far less importance than the products of moisture that are the chief cause of poor visibility over eastern sections.

A fair indication of relative weather conditions may be had from a comparison of the number of cloudy days over different portions. A cloudy day is one on which the average cloudiness was equal to eight-tenths or more of an overcast sky. Over Minnesota and Wisconsin the average annual number is 130 to 150, while over the western Dakotas it is 80 to 100, and in the Plains region of Wyoming and Colorado, 60 to 70. In Iowa and eastern Nebraska, it is about 100, in Illinois and eastern Missouri and Arkansas, 110 to 120, while in northern and western Texas, from 30 to 50.

Over all the area low clouds are much more frequent and more prolonged in winter than in summer. Those in summer are largely in connection with thunderstorms, which are usually of short duration as compared with the overcast rainy or snowy conditions of winter. In winter, clouds that are low enough to be a hindrance to flying are usually associated with fogs, mists, snows, and other forms of low visibility.

The distinction must be made between the number of days on which unfavorable conditions of ceiling and visibility are recorded as occurring sometime during the day, and the number of days that they are persistent throughout the day, as in the former case a flight may merely be delayed, while in the latter it may have to be canceled for the day. The relation of the former to the latter is at least 2 to 1. The proportion is smaller in winter than in summer; that is, a poor condition is more likely to persist throughout the day in winter than in summer; it is also more likely to persist throughout the day over eastern sections of the district than over western sections.

In any generalization such as this, exception must be made of local peculiarities. For example, river valleys are more susceptible to radiation fogs than surrounding

[4] Weather Forecasting in the United States, Chap. IX.

more elevated regions. On the other hand, over the more rugged portions of the country, places that rise quite high above their surroundings are subject to more frequent low ceilings.

For the area as a whole, it may be said that clouds lower than 1,000 feet (300 meters) occur on an average two or three times as often in winter as in summer, and probably twice as often at night and early morning as in the afternoon. They are generally rare on summer afternoons, except as they occur in thunderstorms. From meager statistics available, an approximation may be made that over the eastern portion of the area, a condition of low clouds, or of dense fogs, or heavy rains or snows, is recorded as occurring some time within the 24 hours on probably 20 to 30 per cent of the days in winter, while in summer the frequency may be about half that amount. Over the western portion, this frequency dwindles to perhaps half those figures for the western fringe of the area, possible even less for the extreme southwestern portion. If we consider only those days on which unfavorable conditions persisted throughout the day, the number will diminish to not more than two or three days a month in the colder season, and to practically none in the summer months, even over the least-favored sections in the east.

Visibility is better in summer than in winter, and better in the afternoon than at night or morning, probably averaging poorest in the early morning daylight hours when fogs and haze abound. Over the eastern portion of the area, visibility less than a third of a mile (0.5 kilometer) occurs on about 6 to 8 per cent of the days on winter mornings, and about 3 per cent of the days on summer mornings; on about 4 to 6 per cent of the days on winter afternoons, and 1 to 2 per cent of the summer afternoons. Visibility greater than three miles (5 kilometers) prevails during about 70 to 85 per cent of the time. Over western sections, statistics if available would show a decidedly more favorable condition.

ROCKY MOUNTAIN STATES

By HARRY M. HIGHTMAN

[Weather Bureau Airport, Salt Lake City, Utah]

Ceiling and visibility are perhaps of more importance to aviators in the Rocky Mountain region than in any other part of the country, owing to the fact that airways must traverse regions of great variations in elevation. Airplanes traversing a course over this region must pass over wide expanses of rough broken country, uninhabited desert areas, high mountain ranges, sometimes rising abruptly 4,000 feet (1,200 meters) or more above the general surface level, or through mountain passes, often narrow, with mountain peaks towering above in the near vicinity. Thus ceilings and visibilities that would be considered ample for flights in other parts of the country could not be considered at all for flights in this region.

On account of the great variation in surface elevations along the airways in this region, ceiling heights are very variable, and a determination of the average height along an airway would be of little value. However, it may be stated that the average height of ceilings in the Rocky Mountain region is greater than the average height in other parts of the country. At Salt Lake City, for example, it has been found that ceilings are seldom low enough to measure by means of a ceiling light, or ceiling balloons, that is, lower than 2,000 feet (600 meters), except when precipitation is occurring, or fog prevailing.

Ceilings low enough to interrupt airplane traffic are due almost invariably to low-lying clouds, or fog, in the higher mountain regions which obscure the mountain tops and close in the mountain passes. The most important and frequent causes limiting visibility are fogs, heavy snow, and floating frost in the air. The causes limiting visibility to a lesser extent are smoke, usually occurring in the vicinity of cities, dust storms, and occasionally blowing snow and heavy rain.

Low clouds in the Rocky Mountain region nearly always occur in connection with a low or cyclone over or in the vicinity of this region. Often ceilings are high enough for flights in the lower valleys and comparatively level plateau regions, but too low to allow flights in the mountain region.

Fogs are almost wholly a winter-time phenomenon in the Rocky Mountain region. They are nearly always of the radiation type and form most frequently in the mountain valleys and over the plateau regions. They are more frequent and extensive when the country is snow covered and an anticyclone has settled over the region. These fogs occasionally cover wide expanses of the country in the region surrounding Great Salt Lake, and sometimes continue without a break for a week or longer at a time. Their depth is usually not very great and it is often possible to fly over them.

Heavy snow, most frequently occurring in the mountain regions as snow squalls, is the next in importance to fog as an element limiting visibility. These squalls, usually local and limited in area, often set in suddenly in the mountain regions, blotting out passes and mountain sides, and are thus a serious menace to flying. They are one of the most difficult elements to deal with in airways forecasting in this region.

Frost in the air (floating frost crystals) usually occurring with fog formation, is not an infrequent occurrence in the Rocky Mountain region during periods of cold weather in winter, and sometimes materially restricts visibility. This phenomenon is often observed with a clear sky prevailing overhead, and with a temperature of 10° to 15° F. (−12° to −9° C.) or lower.

Smoke occasionally becomes dense enough during the winter months in the vicinity of the larger cities materially to restrict visibility, especially at nighttime. A mixture of fog and smoke is a quite common occurrence in the vicinity of Salt Lake City during the winter months, and occasionally becomes dense enough to prevent landings and take-offs.

Dust storms occur occasionally over the desert regions, during dry periods of summer and autumn, when high winds prevail. Dust is sometimes lifted several thousand feet in the air and occasionally becomes dense enough to obscure landing fields.

There is very little interruption to flying owing to poor ceiling and poor visibility in the Rocky Mountain region during approximately seven months of the year; that is, from May to November, inclusive. During May and November some of the higher mountain passes may be closed in by low clouds during stormy periods, but this condition seldom lasts as long as a day at a time, and probably the average occurrence is less than three times during a month. From December to April, inclusive, conditions are very unfavorable for flying approximately one-sixth of the time. The three winter months, December, January, and February, are decidedly the worst.

PACIFIC COAST STATES

By DELBERT M. LITTLE

[Oakland Airport Station, Oakland, Calif.]

Cloudiness along the Pacific coast is caused by three major meteorological processes and each process produces a separate type of ceiling. First, forced ascending currents of moist air over mountain ranges and in cyclonic circulations produce the greatest amount of cloudiness and the greatest variance in heights of ceiling. Since Washington and Oregon are nearer to the normal paths of storms entering the continent, the region from the Pacific Ocean to the Cascade Mountains and from extreme northern California to the Canadian border is the cloudiest on the Pacific slope.

There are five mountain ranges averaging from 3,000 feet to 8,000 feet (900 to 2,400 meters) elevation lying across the airway between Los Angeles and Portland. The amount of cloudiness and ceiling heights over these mountain ranges depend upon the strength of the cyclonic winds of oceanic origin together with the proximity of the barometric depression. Ceilings are always higher over the valleys and lower in the mountains when cyclonic conditions produce cloudiness. A very general rule in estimating the degree of safety for a proposed flight over mountain ranges on the Pacific coast is as follows: With airway weather reports along the proposed flight showing varying amounts of cloudiness and heights of ceiling, and a weather map showing a cyclonic circulation bringing winds from the Pacific, the possibility of flight over the mountain ranges on the average is inversely proportional to the pressure gradient. For example, under the above conditions a barometric pressure gradient of less than 0.10 inch in 300 miles (2.5 millimeters in 500 kilometers) would indicate a flight could probably be made on schedule; a pressure gradient of from 0.10 to 0.20 inch in 300 miles (2.5 millimeters in 500 kilometers) would indicate cautionary flying weather with a possibility of getting through; a pressure gradient of 0.20 to 0.30 inch in 300 miles (5 to 7.5 millimeters in 500 kilometers) usually means impossible and dangerous flying weather.

The second process through which considerable cloudiness is produced on the Pacific coast is a radiation process and occurs mainly during the late spring, summer, and early autumn. During this period of the year the desert regions and interior valleys of California, frequently including the interior valleys of Oregon and Washington, are heated through insolation during the summer days. The temperature in these valleys often exceeds 90° F. (32° C.), resulting in expansion of air over these areas producing a thermal cyclone[5] sometimes called a "heat-low." Cloudiness is seldom present over the area of the thermal cyclone, but cool moist air from the Pacific Ocean flows inland over low ground, bays, inlets, and gaps in the coast hills. Ocean fog and low stratus clouds usually prevail over the ocean along the entire Pacific coast during this season. The movement of cool moist air from the ocean to the land is attended by fog or stratus clouds moving inland but dissipating during the day as it underruns the heated inland air. All land areas from the coast to the mountain ranges near the coast, including all coastal valleys, bays, and inlets are thus filled with cool moist ocean air which has forced the heated dry inland air up to an elevation of from 1,500 to 4,000 feet (457 to 1,219 meters) above the surface. During the night the movement of ocean air inland gradually ceases. Both the warm dry air mass aloft and to a greater extent the cool moist air mass near the surface lose heat during the night due to radiation. Stratus clouds are formed by condensation beginning in the cool moist layer of air near the elevation at which the warm dry air overlies it. Numerous aerographic flights at San Diego by the Navy and eye observations while in flight over the San Francisco Bay area evidence the fact that the top of the stratus cloudiness along the coast is at the elevation where a rapid temperature inversion begins. Since cool moist air movement from the ocean to the land is required the most favorable pressure distribution for the air movement and resultant cloudiness is when isobars are parallel to the coast line. On the other hand, clear skies will prevail along the coast when a high-pressure area is pushing inland near the California-Oregon boundary and isobars are lying at such an angle transversely with the coast that the air movement is practically parallel to it.

Surface humidities of 65 to 70 per cent or greater during the late afternoon at coastal valley stations 10 or 12 miles (16 to 19 kilometers) inland are nearly always necessary for the general formation of the cloudiness in the coastal valleys. Ceiling heights vary from a few hundred feet to extremes of nearly 4,000 feet (1,219 meters) and the thickness of the layer of cloudiness varies from a few hundred feet to sometimes 3,000 feet (914 meters). Undoubtedly the height of ceiling depends upon the depth of the layer of cool moist air moving in from the ocean. This is not easily determined from the surface but an examination of weather maps in relation to ceiling leads to the following general indications:[6] If the thermal cyclone over the interior is long and narrow, the depth of ocean air moving inland will be shallow and ceilings along the entire coast will be low, usually below 1,000 feet (304 meters). If the thermal cyclone spreads out over Nevada and southern Utah ceilings along the California coast will be relatively high, 1,500 to 3,000 feet (457 to 914 meters) due to a deeper stratum of ocean air moving inland. If the northern end of the thermal cyclone is narrow and the southern end is wide, ceilings will be low along the northern California coast and high along the southern California coast. Skies over the interior valleys are usually clear at such times.

The third type of cloudiness or condensation is also a radiation phenomenon, but confined to the interior valleys of the Pacific coast region during the winter months. It is formed at the surface over interior valleys and the ordinarily relatively thin layer sometimes reaches an extreme thickness of nearly 4,000 feet (1,219 meters). An ideal condition for its formation is that following the passage of a cyclone southeastward through Oregon, Nevada, and southern Utah when a strong high-pressure area develops in the rear of the storm over the Plateau region. The interior valleys of California, Oregon, and Washington become filled with moist air during the passage of the storm and after skies have cleared, outgoing radiation exceeds incoming radiation, with a resulting net loss of heat. In this case temperature inversion is at the surface with radiation greatest near the ground, hence condensation begins at this level and proceeds upward. Because of the short days and long nights, insolation can not overcome radiation and the fog continues to build up over the interior valleys for sometimes as much as three weeks at a time. The

[5] Monthly Weather Review, August, 1929, The West Coast Atmospheric Fault, by Edward H. Bowie.

[6] Studies of George M. French, Weather Bureau official at Los Angeles, Calif.

ceiling is usually on the ground during such periods, but often lifting during the middle of the day. A change in pressure distribution producing moderate to fresh upper air winds is required before the fog or condensation is driven out of the interior valleys by air movement.

Visibility in the Pacific coast region may be said to vary with the seasons, if restricted visibility due to fog or storms is not considered. During the late spring, summer, and early autumn very little precipitation occurs over the entire area and upper air winds are usually light. Consequently the air over the area from the Rocky Mountains westward accumulates haze and forest-fire smoke during the season and is seldom washed out by rain or drifted away fast enough by air movement. If the season is unusually dry, forest fires are numerous and a smoky condition steadily increases as the season progresses. During the 1929 season, for example, visibility was reduced to one-fourth mile (0.4 kilometer) over Washington and Oregon, with smoke extending up to 10,000 feet (3,047 meters), resulting in suspension of much flying during a 2-weeks period in August of that year. A general rain over the district during such a period will clear the atmosphere and visibility will remain good for a week or 10 days following. Strong northerly winds at moderate and high elevations will always clear the atmosphere and make visibility excellent for several days. During "north-wind days" pilots have many times reporting seeing Mount Rainier, near Seattle, Wash., and Mount Shasta, in northern California, while flying at high elevations over central Oregon.

At times of marked temperature inversion there is an optical phenomenon known as a mirage, which affects the earthward visibility for a pilot flying above the inversion surface. It is more pronounced during the summer period and near the coast where the inversion is greatest. From the air it may be so pronounced as to have the appearance of a layer of fog, except that directly below the plane, ground objects can be faintly seen. From a point near the level where inversion begins, the top of the cool moist layer has the appearance of a line on the horizon above which an apparent layer of exceptionally clear air about 1° wide prevails. This reflection phenomenon appears to the pilot during the daytime and disappears to him at night. Cities and airports not discernible at an angle from the plane during the day are readily seen under the same conditions at night and the false impression to the pilot is that smoke, haze, or fog has disappeared.

AVERAGE VISIBILITY AT CHICAGO AIRPORT

By F. H. WECK

The accompanying figure shows the daily march of horizontal visibility at the Chicago Airport for the first three months of 1930. The main contributing factor of reduced visibility is one of smoke. Contrary to the old adage, the darkest hour is not just before the dawn.

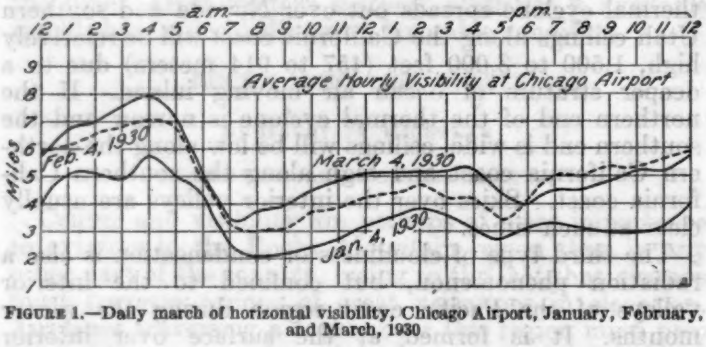

FIGURE 1.—Daily march of horizontal visibility, Chicago Airport, January, February, and March, 1930

Stoking furnaces in homes fills the air with smoke after the man of the house arises, and the visibility falls rapidly. As the day advances the smoke becomes lighter and the visibility improves. Then in the early morning there is more haze and fog which disappear with the rise in temperature.

Firing in the afternoon at residences and banking furnaces at factories again reduce the visibility, after which it begins to rise. From the graph it appears that mail planes would have better flying conditions if they were scheduled to arrive in Chicago between 1 and 4 a. m. Most of them are due at from 5 to 8 a. m. and from 6 to 8 p. m.

As a further evidence that the visibility varies inversely as the amount of coal consumed, it is noted that from 6 p. m. till midnight the average visibility was less for March than for February. The mean temperature at 7 p. m. was 37.8° for February and 36.3° for March. Also the 7 a. m. mean temperature was 31.5° for February and 29° for March, but there was more fog during the month of February.

The average visibility for January was 3.6 miles, for February 4.8, and for March 5.2.

There is no scientific method used in obtaining values of visibilities. The ground around the airport is more or less level and a number of "visibility points" of known distance from the place of observation afford fairly reliable data.

FIGURE 1.—One of the three funnel clouds observed, photographed from Greensburg

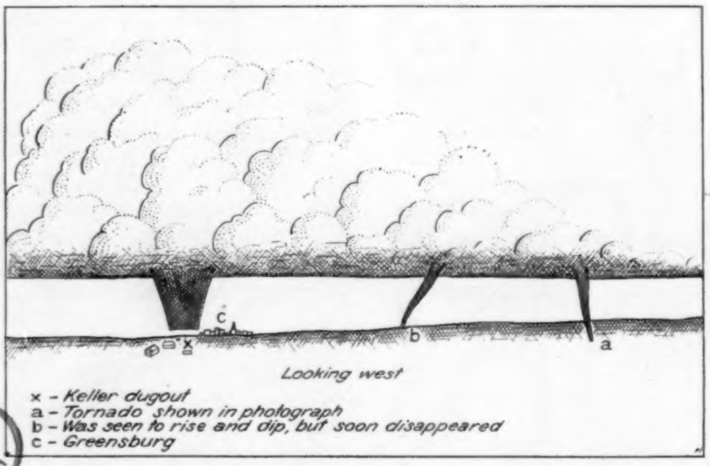

FIGURE 2.—Sketch of tornado funnel clouds from description by Mr. Keller. Looking west from his residence

SEEING THE INSIDE OF A TORNADO

By ALONZO A. JUSTICE

[Weather Bureau office, Dodge City, Kans.]

Although the incidents herein set forth occurred nearly two years ago, it is thought that they are sufficiently interesting to be reported even at this date. It was just 16 months to a day from the time the events happened that the writer heard a direct account of them from the man whose extraordinary experience forms the basis of this story.

Mr. Will Keller, a farmer of near Greensburg, Kans., is the man to whom reference is made, and the following is substantially his story:

It was on the afternoon of June 22, 1928, between 3 and 4 o'clock. I was out in my field with my family looking over the ruins of our wheat crop which had just been completely destroyed by a hailstorm. I noticed an umbrella-shaped cloud in the west and southwest and from its appearance suspected that there was a tornado in it. The air had that peculiar oppressiveness which nearly always precedes the coming of a tornado.

But my attention being on other matters, I did not watch the approach of the cloud. However, its nearness soon caused me to take another look at it. I saw at once that my suspicions were correct, for hanging from the greenish-black base of the cloud was not just *one* tornado, but *three*. See Figure 2.

One of the tornadoes was already perilously near and apparently headed directly for our place. I lost no time therefore in hurrying with my family to our cyclone cellar.

The family had entered the cellar and I was in the doorway just about to enter and close the door when I decided that I would take a last look at the approaching tornado. I have seen a number of these things and have never become panic-stricken when near them. So I did not lose my head now, though the approaching tornado was indeed an impressive sight.

The surrounding country is level and there was nothing to obstruct the view. There was little or no rain falling from the cloud. Two of the tornadoes were some distance away and looked to me like great ropes dangling from the clouds, but the near one was shaped more like a funnel with ragged clouds surrounding it. It appeared to be much larger and more energetic than the others and it occupied the central position of the cloud, the great cumulus dome being directly over it.

As I paused to look I saw that the lower end which had been sweeping the ground was beginning to rise. I knew what that meant, so I kept my position. I knew that I was comparatively safe and I knew that if the tornado again dipped I could drop down and close the door before any harm could be done.

Steadily the tornado came on, the end gradually rising above the ground. I could have stood there only a few seconds but so impressed was I with what was going on that it seemed a long time. At last the great shaggy end of the funnel hung directly overhead. Everything was as still as death. There was a strong gassy odor and it seemed that I could not breathe. There was a screaming, hissing sound coming directly from the end of the funnel. I looked up and to my astonishment I saw right up into the heart of the tornado. There was a circular opening in the center of the funnel, about 50 or 100 feet in diameter, and extending straight upward for a distance of at least one half mile, as best I could judge under the circumstances. The walls of this opening were of rotating clouds and the whole was made brilliantly visible by constant flashes of lightning which zigzagged from side to side. Had it not been for the lightning I could not have seen the opening, not any distance up into it anyway.

Around the lower rim of the great vortex small tornadoes were constantly forming and breaking away. These looked like tails as they writhed their way around the end of the funnel. It was these that made the hissing noise.

I noticed that the direction of rotation of the great whirl was anticlockwise, but the small twisters rotated both ways—some one way and some another.

The opening was entirely hollow except for something which I could not exactly make out, but suppose that it was a detached wind cloud. This thing was in the center and was moving up and down.

The tornado was not traveling at a great speed. I had plenty of time to get a good view of the whole thing, inside and out. It came from the direction of Greensburg, which town is 3 miles west and 1 mile north of my place. Its course was not in a straight line, but it zigzagged across the country, in a general northeasterly direction.

After it passed my place it again dipped and struck and demolished the house and barn of a farmer by the name of Evans. The Evans family, like ourselves, had been out looking over their hailed-out wheat and saw the tornado coming. Not having time to reach their cellar they took refuge under a small bluff that faced to the leeward of the approaching tornado. They lay down flat on the ground and caught hold of some plum bushes which fortunately grew within their reach. As it was, they felt themselves lifted from the ground. Mr. Evans said that he could see the wreckage of his house, among it being the cook stove, going round and round over his head. The eldest child, a girl of 17, being the most exposed, had her clothing completely torn off. But none of the family were hurt.

I am not the first one to lay claims to having seen the inside of a tornado. I remember that in 1915 a tornado passed near Mullinville and a hired man on a farm over which the tornado passed had taken refuge in the barn. As the tornado passed over the barn, the door was blown open and the man saw up into it, and this one like the one I saw, was hollow and lit up by lightning. As the hired man was not well known, no one paid much attention to what he said. [Mr. Keller thought that this tornado was the one shown in photograph opposite p. 448 of MONTHLY WEATHER REVIEW of 1919.]

According to Mr. L. E. Wait, president of the Greensburg State Bank, the tornado passed the outskirts of Greensburg, striking and demolishing some outhouses. As it passed Greensburg it swept the ground and made a noise like distant heavy hail. Mr. Wait and others watched it as it traveled eastward toward the Keller farm and saw it rise from the ground. Mr. Wait said that from the rear it looked like a "sawed-off cylinder."

From Mr. Wait the writer first heard of Mr. Keller's experience. Mr Wait made a trip from Greensburg to Dodge City, a distance of 50 miles, bringing Mr. Keller with him for the express purpose of having him relate his experience to the writer.

From Mr. Wait and members of his family and from Mr. Corns, cashier of the Greensburg State Bank, the following additional account of the actions of the tornado was gathered.

After leaving the Evans farm it continued to "bounce" (as one witness described it) its way across the eastern half of Kiowa County and was last heard of in Pratt County. It left a path here and there where it struck the ground, not of wrecked buildings, for there were no more buildings in its path after the Evans farm, but of torn-up ground. It tore holes and plowed furrows from a few inches deep to several feet deep.

Mr. Corns said that he saw a furrow which it plowed across a field of wheat. The furrow was from 2 to 3 feet wide and as deep as the ground had been plowed, about 6 inches. The dirt was thrown over on each side of the furrow just as it might have been if a plow had made it.

A farmer whose land had been marked by the tornado said that it made a furrow "deep enough to bury a horse in."

Mr. William Cobb, resident of Greensburg and owner of a number of farms in Kiowa County, said that the tornado crossed one of his pastures of buffalo-grass sod and that it plowed a furrow a mile long, in places from 4 to 6 feet deep, and that the whole thing looked like "where there had been a grading for a railroad." The dirt was piled along the side of the furrow, just as if thrown there by hand or plow or dragged there by scrapers. It was reported that farmers used scrapers

and horses to level up the ground where the tornado had disturbed it.

Mr. Wait made a trip from Greensburg eastward along the path which the tornado traveled, for the purpose of obtaining, if possible, photographs of some of the torn-up ground. But the trip was made 18 months after the occurrence of the tornado and the land including the Cobb pasture, had all been twice sown in wheat and only a few faint traces could be found.

Mr. Keller is a man apparently between 35 and 40 years of age. His reputation for truthfulness and sobriety is of the best. Apparently he is entirely capable of making careful and reliable observations.

TORNADO AT GRAND RAPIDS, MICH., MAY 2, 1930

By WILLIAM H. TRACY

[Weather Bureau Office, Grand Rapids, Mich.]

The most destructive local windstorm of which there is any record struck this city during the early morning of May 2. Storm was of true tornado or "twister" type and was apparently one of a series of similar storms that occurred in southern Michigan during the night of May 1–2.

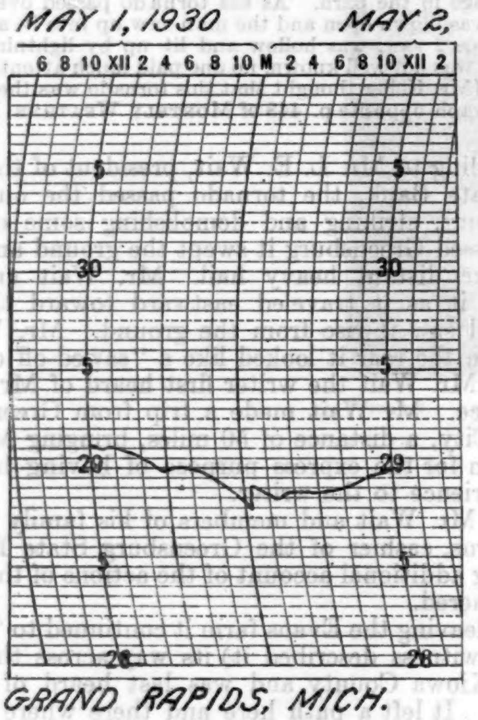

FIGURE 1.—Barograph trace during passage of the tornado

The maximum force of the storm struck this city at 12:32 a. m., central standard time, when the Weather Bureau anemometer on the roof of the Grand Rapids National Bank Building registered an extreme velocity of 72 miles an hour from southwest. Anemometer is located 1¼ miles from the nearest point in the storm's path. Pressure had been falling steadily since noon of May 1, due to a storm center of considerable magnitude over northern Manitoba; during the passage of the storm there was an abrupt rise of 0.12 of an inch. (See Fig. 1). Wind was from south-southwest prior to the storm and veered to west-northwest after its passage. Heavy rain began at 12:29 a. m., and 0.23 of an inch fell in 9 minutes; rain continued, but at a slow rate; hail accompanied the rain from 12:32 a. m. to 12:37 a. m.; hailstones were about one-quarter inch in diameter and caused no damage. Thunderstorms and high temperatures for the season were general throughout the middle and upper Mississippi valleys during the afternoon and night of May 1.

The first point where material damage occurred is in the southwest portion of the city about one-half mile from the eastern bank of the Grand River. The storm followed a course that was somewhat southeast of northeast, passing from the factory district through part of the best residential section, and the last indication of tornadic action was in the Hodenpyle woods, near the northern shore of Reeds Lake; the path was approximately 4 miles long and its width about 350 feet.

Due to darkness no "funnel" cloud or other peculiar cloud formation or glow was observed, although progress of the storm was carefully noted by observer on duty at this office. That this storm was a true tornado is indicated by the fact that destruction was not uniform along the path, but showed several points of maximum damage; the roar or rumble that is typical of tornadoes was reported by several parties, and was distinctly heard by the undersigned, who resides about 750 feet from the path. Felled trees along the path were lying with their roots to the southwest and their tops to the northeast on the north side, and with their roots to the northwest and tops to the southeast on the south side of the path. Another excellent indication of its tornadic character is shown in the damage at the Luce Furniture Co.'s factory and the building of the Columbian Storage Co.; both of these cases the walls were blown out by the exertion of the inside pressure, and the débris thrown into the street; several large plateglass windows along the path showed this same influence.

The total estimated damage of $1,000,000 as given in the newspaper reports has been checked as far as possible and seems reasonably correct. The greatest damage was in the factory district, where the storm struck first, and to telephone, electric power, and street railway lines; about 70 per cent of the total damage occurred here. The loss to the individual property owner was relatively light, but the area affected was large. It is estimated that 1,500 shade trees were either thrown down completely or seriously damaged.

No loss of life occurred, and only two persons were slightly injured, both by falling débris. The fact that the storm occurred at night when factories were closed and few people were on the street accounts for no deaths and few injuries.

Only four well-defined tornadoes have been recorded in this city since the establishing of a Weather Bureau station here. The damage occasioned by that of May 2, 1930, is much greater than occurred in any of the previous storms.

TORNADOES IN MICHIGAN IN MAY, 1930

By DEWEY A. SEELEY

[Weather Bureau Office, Lansing, Mich.]

On the morning of May 2, 1930, much destruction occurred in Michigan due to tornadoes. Outside of Grand Rapids severe local storms, evidently tornadic in character, were reported in many places in the west-central portion of the State. These occurred between 2 and 3 a. m. eastern standard time. A map is inclosed indicating points where destruction occurred. It is evident that there were at least a half-dozen tornadoes, traveling in nearly parallel paths, the paths varying in width from a few rods to 1 mile and the length from 25 miles to 75 miles. The general direction of these paths was east-northeastward and they were in some cases only 5 or 6 miles apart. Several places where destruction occurred were visited by employees in this office and there were numerous evidences that the storms were true tornadoes. The débris from buildings was scattered in various directions and in a number of instances timbers were driven into the ground 18 inches and more and at various angles. In most cases the destruction occurred on higher elevations, the storms passing over adjoining low areas without causing damage.

Hail was reported in and near the paths of the storms in a majority of cases. The usual terrific roar was mentioned by a number of people in the storm paths and a few observed a funnel cloud, although, there were not many who so reported, probably due to the hour that the storms occurred. Thunder and lighting prevailed during the storms and several buildings were damaged by lightning. Many farm animals were killed, but no loss of human life resulted and very few injuries were reported.

Damage in the city of Grand Rapids has already been estimated at $1,000,000. It is believed that the damage elsewhere in the State exceeded $200,000.

May 13, 1930.—On the afternoon of May 13, about 3 p. m. eastern standard time, a severe storm did considerable damage in Clinton County, Mich. The storm originated in the western portion of the county, near Westphalia. It traveled east-northeast and disappeared near Ovid, Mich., covering a distance of about 25 miles. The path was unusually wide, exceeding one-half mile over a portion of the route. The storm passed over open country where buildings were scattered, missing towns and villages. A total of 32 farm barns were wrecked, a number of residences damaged and many smaller buildings destroyed, one concrete milk house being picked up and carried about five rods. A portion of the loss was due to the destruction of valuable timber and a number of orchards were completely uprooted. The storm was tornadic in character. Many persons observed the funnel-shaped cloud and the resulting débris showed the characteristic distribution due to the revolving motion of the storm. Maple trees with trunks 2 feet and more in diameter were splintered and twisted, making a complete turn and more.

Heavy hail occurred in connection with the storm. Hail stones as large as walnuts and hen's eggs were reported. The usual deafening roar and the attending heavy thunder and lightning were commented on by many persons in the vicinity.

This storm traveled over a portion of the same path that a previous tornado followed on March 28, 1920, and some of the same buildings were damaged by both storms. The total loss was estimated as exceeding $200,000.

May 23, 1930.—On the afternoon of May 23 a tornado did considerable damage in Michigan. The storm apparently originated in the north-central portion of Isabella County and traveled northeastward across portions of Clare, Gladwin, and Ogemaw Counties. It passed through the town of Clare and also through portions of the towns of Gladwin and West Branch. The storm was reported to be one-half to 1 mile wide and about 70 miles in length. The storm exhibited the typical characteristics of a tornado, lifting off roofs of buildings, twisting off trees and windmills, and scattering débris in all directions along its path. Several persons reported

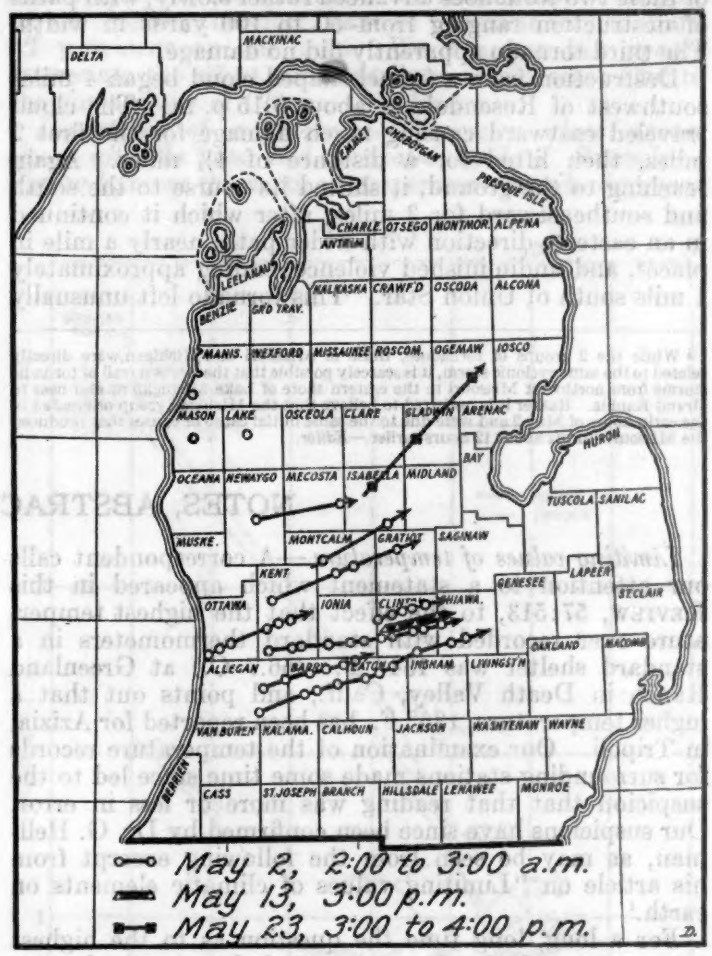

FIGURE 1.—Approximate tracks of the Michigan tornadoes of May 2, 13, and 23, 1930

seeing the usual funnel cloud. Many barns, silos, and other structures were leveled to the ground and the total damage to property was estimated at $250,000. A few persons were injured, but none was killed. A number of farm animals were lost.

Very little hail attended this storm, although some was reported in the vicinity of Clare.

The storm originated about 1:30 p. m. and reached the end of its path about 3:10 p. m. About one-half hour later some damage occurred near Hubbard Lake and Alpena, Mich., which is about 40 miles northeast from the last damage caused by the "twister" and apparently on about the same line extended. The damage in the later section was reported to have been caused by a straight blow or "line squall."

The approximate paths of the several tornadoes are shown in Figure 1.

TORNADOES IN MISSOURI [1]

By W. S. BELDEN

[Weather Bureau Office St. Joseph, Mo.]

Mr. W. S. Belden in charge of the Weather Bureau Office of St. Joseph, Mo., reports the occurrence of at least four tornado funnel clouds, three of which were first seen over the Missouri River a little north of White Cloud, Kans., about 6 p. m. May 1, 1930. One moved nearly due east for a distance of about 5 miles and disappeared a little south of Napier, Mo. Another moved northeasterly a distance, approximately, of 11 miles from Mound City to a point north of Maitland, Mo. Each of these two tornadoes advanced rather slowly, with paths of destruction ranging from 50 to 100 yards in width. The third tornado apparently did no damage.

Destruction from a funnel-shaped cloud began 4 miles southwest of Rosendale at about 6:15 p. m. The cloud traveled eastward causing much damage for the first 2 miles, then lifted for a distance of 4½ miles. Again reaching to the ground, it shifted its course to the south and southeastward for 3 miles, after which it continued in an easterly direction with wider path, nearly a mile in places, and undiminished violence, ending approximately 1 mile south of Union Star. This tornado left unusually wide trails of destruction, having a total length of slightly more than 10 miles.

The last of the group of tornadoes was first observed 4 miles north of Filmore at about 6:20 p. m. It moved northeastward 4 miles, then followed a sinuous course eastward for nearly 3 miles, and turned southeastward for about 1 mile on the west side of the One Hundred and Two River Valley, after which it turned eastward again, crossed the river and disappeared one-fourth mile south of Bolckow. The path of the funnel-shaped cloud varied from 100 to 200 yards in width and was continuous for 8 miles.

No lives were lost in these violent storms and no one was seriously injured. Many escapes were made in automobiles when the tornadoes were observed approaching, while others took refuge in caves, cellars, and basements. Approximately 60 homes were damaged or totally destroyed and a much larger number of other farm buildings were demolished. One school building and one filling station were also wrecked. Numerous farms suffered serious losses of machinery, livestock, trees, and fences, but there was little damage to growing crops, such as wheat, oats, and alfalfa. Clearing fields of débris involved much labor.

A conservative estimate of the total loss in both Holt and Andrew Counties as a result of these tornadoes has been placed at $200,000.

[1] While the 2 groups of tornadoes, those of Missouri and Michigan, were directly related to the same cyclonic storm, it is scarcely possible that there was a trail of tornadic storms from northwest Missouri to the eastern shore of Lake Michigan at and near to Grand Rapids. Rather it is preferred to believe that the Michigan group originated in the early hours of May 2 and were due to the same initial cause or causes that produced the Missouri storms about 12 hours earlier.—*Editor.*

NOTES, ABSTRACTS, AND REVIEWS

Limiting values of temperature.—A correspondent calls our attention to a statement which appeared in this REVIEW, 57:513, to the effect that the highest temperature ever recorded with standard thermometers in a standard shelter was 134° F. (56.7 C.) at Greenland Ranch in Death Valley, Calif., and points out that a higher temperature, 136° F., has been reported for Azizia, in Tripoli. Our examination of the temperature records for surrounding stations made some time since led to the suspicion that that reading was more or less in error. Our suspicions have since been confirmed by Dr. G. Hellman, as may be seen from the following excerpt from his article on "Limiting values of climatic elements on earth.[1]

For a long, long time the question as to the highest temperature observed on the earth has been of great interest, but it is difficult to answer it with certainty, since the exact determination of high air temperatures encounters great difficulties on account of the not easily eliminated error due to thermometer exposure or, with aspirated and sling thermometers, on account of radiation from the ground. When the ground in the desert is heated to 158° F. it is difficult to prevent ground radiation from affecting the thermometer. It may, therefore, be assumed as a matter of course that the maximum temperatures recorded are rather too high than too low, and the error may be taken as approximately two-tenths of a degree.

The highest temperature recorded in a fixed shelter (United States shelter of the Stevenson screen type) was 134° on July 10, 1913, in Death Valley, Calif. This unusual heat, which was probably exceeded at the lowest point in the depression, occurred in a 7-day period of extraordinary heat, which gave the following maxima:

July, 1913

8th	128°	11th	129°	13th	131°
9th	129	12th	130	14th	127
10th	134				

In all probability such a series of extreme temperature values rarely occurs even in Death Valley.

In the interior of New South Wales 129° and even 131° were recorded on January 21, 1845 (Hann *Klimatologie* III, 485). At several points in the North American desert, comprising parts of Arizona, California, and New Mexico, for example, Salton, Mammoth Tank, and Mohawk Summit, there have been recorded maxima of 124° to 130° (ibid. III, 425 ff.). At Basra, on the lower Euphrates, 129° was read in July, 1921 (Quarterly Journal, Royal Meteorological Society, 1922, 278). Rohlfs recorded a temperature of 127° in Kauar Oasis (19° N., 13° E.) and values almost as high in the desert region of India; Jacobabad, 126° on July 13, 1897.

We read here and there of still higher temperatures than those just mentioned, but they are either to be immediately characterized as false or so questionable and improbable as not to merit mention here. (See *Meteorologische Zeitschrift*, 1893, pp. 62 and 279.) I believe that we may accept 131° to 133° as the highest observed temperature that is sufficiently authenticated; the temperature of 134° recorded in the shelter in Death Valley is probably 2° or more too high on account of the influence of radiation in heating the shelter, which was at only moderate height above the ground.

Recently I noticed in the Quarterly Journal of the Royal Meteorological Society, 1924, page 324, and in the

[1] Sitzungsberichte der Preussischen Akademie der Wissenschaften. Physikalisch-Mathematischen Klasse. XI. 1925.

Meteorologische Zeitschrift, 1925, page 39, that according to a statement by F. Eredia in his paper, *Il clima di Azizia, Tripolitania,* there was recorded at Azizia, about 30 miles southwest of Tripoli, a maximum temperature of 136.4° on September 13, 1922, under conditions of cloudless sky and wind from the southwest. At once it appeared to me as striking that a temperature so high should occur relatively near the sea and in a region of only semidesert character. A comparison with the remaining Tripolitanian stations in the *R. Ufficio Agrario, Sezione Meteorogica, Nr. 4, 5,* showed that the reading is about 20° higher than the maxima on the same day and on the preceding day at other stations: Tripoli, 115°; Sidi Mesri, 111°; Homs, 112°; and Zuara Marina, 117°. Also in the year 1923, when the publication gives 135° as the maximum for Azizia, all of the remaining stations, nine in number, have maximum temperatures 18° or more degrees lower. On the other hand it appears to me to be striking that the minima observed at Azizia are lower than those recorded at the other stations. I am, therefore, inclined to believe that there is defective shelter against radiation or that the thermometer is located in a hollow.—*A. J. H.*

Memoir of the Institute of Meteorology, No. 1—Climatic Provinces of China by Coching Chu.—Published by the Institute of Meteorology, National Research Institute, Nanking, China, April, 1929.—The Nanking Institute of Meteorology established under the auspices of the Research Institute of China, has devoted its first memoir to the question of climatic Provinces of China. Dr. Coching Chu, the director of the new service, and to whom we already owe several contributions to climatological literature on China through his various articles appearing in the MONTHLY WEATHER REVIEW from time to time, points out in his discussion the different criteria that are necessary for the classification of a climate of a country so extensive in area and so diversified in climate as China.

The first part of the memoir is a collection of eight maps—three maps of climatic Provinces of China, one by Koeppen, one by Emm. de Martonne, and one of the new classification submitted by the author; one rainfall map of China by Gherzi; a mean annual isothermal map of China by H. Gauthier; July and January Isothermal maps of China by H. Gauthier; and a hypsometric map of China.

Following the maps is a discussion of 11 pages in which the author discusses the relative merits and demerits of the different classifications referred to in the first part of the memoir, including Prof. Jules Sion's summary, from his book "Asie des Moussons."

In his own classification of the climatic Provinces of China, the author divides China into eight major Provinces based upon the criteria of mean annual temperature, annual range and mean annual precipitation, and also in two Provinces, the mean temperature of the coldest month, and, in two others, cyclones, typhoons, and altitude.

The remarks "In China proper, where the rainfall is abundant, temperature becomes the vital factor" and "with a few exceptions such as Tsingtao, the maximum temperature in China usually occurs in the month of July," are either misleading or need qualification. We sincerely wish the first remark were true, so that the loess highland could enjoy rain equal even to that of Chili, and so that the North China plain would be freed from the agony of famine. In the second remark, the "few exceptions" seem to be too many to be exceptions, for out of the records of 100 stations only 52 stations have July maximum.

The author's distinct contribution lies in the attempt to correlate the climatic provinces with vegetation. Since the paper is a very sketchy one, little information is offered for study. Yet it serves to emphasize the relation between life and climate as a criterion for the classification of climates. The paper serves as a stimulus to a problem for investigation rather than a solution of a problem.

The discussion is concise and clear. The maps are simple but definite. The study of climatology in China, however, is only in its infancy, owing to the lack of data in the inland regions and the lack of knowledge of the upper air. Thus, it is only as in a very dim light that the outline of Chinese climate is distinguishable while the detailed special features are still veiled. Pioneer meteorologists, therefore, have to feel their way to mark off provinces on the map. We can not but deeply appreciate the effort and contribution of Doctor Chu to the climatology of China.—*Liu En-lan.*

Persistence of a pronounced inversion above stratus clouds after the latter had dissipated, by L. T. Samuels.—Figure 1 shows the vertical temperature distribution over

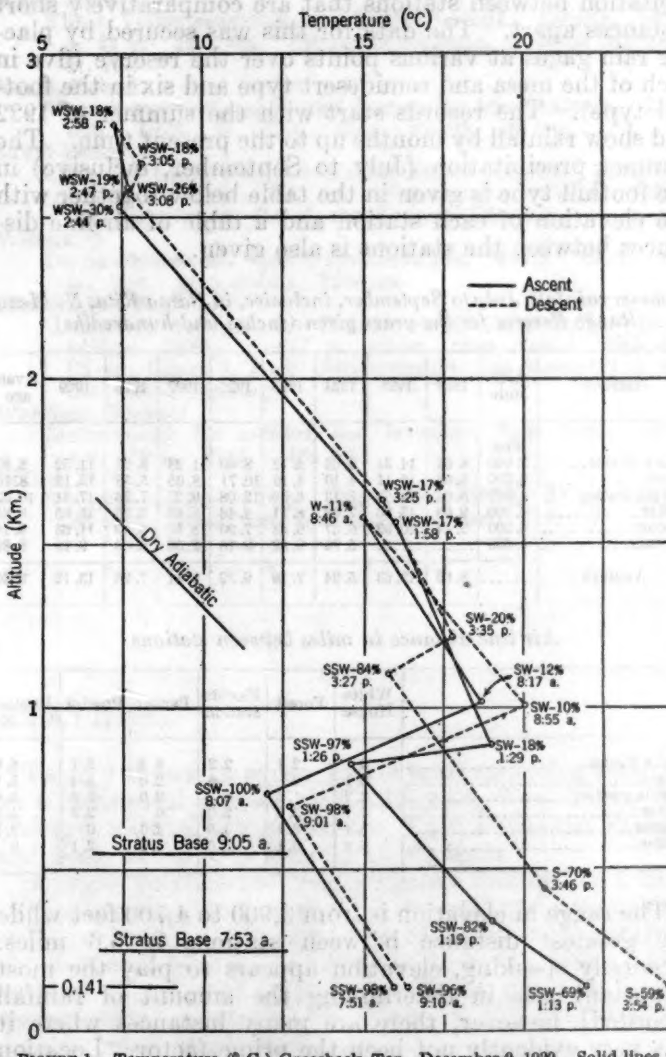

FIGURE 1.—Temperature (° C.) Groesbeck, Tex., December 9, 1920. Solid lines represent the ascent, and broken the descent

Groesbeck, Tex., on December 9, 1929, as observed by kites. Two flights were made and the times at which the meteorograph reached the various levels are indicated, together with the corresponding wind direction and relative humidity. Note the low relative humidities in and above the inversion layer; also the change in wind

direction above the inversion layer to southwest and west from south and south-southwest below this level.

During the first flight (7:51 to 9:10 a. m.) the sky was overcast with stratus clouds and misting rain was recorded from 7 to 8:10 a. m. It will be noted from the graph that the base of the clouds "lifted" from 250 meters at 7:53 a. m. to 550 meters at 9:05 a. m.

By the time the second flight was started (1:13 p. m.) the cloudiness had diminished to less than one-tenth. It will be seen from the graph that the inversion, although less pronounced, persisted after the clouds had disappeared.

The progressive warming of the air from the ground to the top of the inversion level until the inversion itself was considerably reduced is strikingly shown in the graph and illustrates that in this case, at least, the inversion was not a result of the cloud layer but that the upper limit of the latter was determined by the inversion.

Precipitation Records at Santa Rita, New Mexico, Range Reserve [reprinted from Forest Service Branch of Research for February, 1930 (mimiographed)].—Another phase of the rainfall study deals with the variation in amount of precipitation between stations that are comparatively short distances apart. The data for this was secured by placing rain gages at various points over the reserve (five in each of the mesa and semidesert type and six in the foothill type). The records start with the summer of 1922 and show rainfall by months up to the present time. The summer precipitation (July to September, inclusive) in the foothill type is given in the table below together with the elevation of each station and a table of air-line distances between the stations is also given.

Summer rainfall, July to September, inclusive, in Santa Rita, N. Mex., Range Reserve for the years given (inches and hundredths)

Stations	Altitude	1922	1923	1924	1925	1926	1927	1928	1929	Average
	Feet									
White House	3,900	8.04	14.34	3.64	5.12	8.60	11.28	8.23	11.52	8.85
Forest	4,200	8.66	15.11	4.10	4.19	10.71	8.65	5.56	13.13	8.76
Florida station	4,300	8.04	14.53	5.13	6.59	12.08	9.25	7.26	17.31	10.02
Parker	4,700	9.08	13.26	7.03	8.11	8.46	8.63	8.26	15.95	9.85
Proctor	4,200	9.44	10.92	6.37	9.63	7.90	8.57	8.59	11.63	9.18
Ruelas	4,500			5.75	9.52	8.16	12.50	5.66	9.18	8.89
Average		8.65	13.63	5.34	7.19	9.32	9.81	7.26	13.12	9.30

Air line distance in miles between stations

	White House	Forest	Florida station	Parker	Proctor	Ruelas
White House	0	2.1	2.2	4.1	5.1	6.6
Forest	2.1	0	.6	2.0	3.4	5.1
Florida station	2.2	.6	0	2.0	3.6	5.6
Parker	4.1	2.0	2.0	0	2.3	4.3
Proctor	5.1	3.4	3.6	2.3	0	2.1
Ruelas	6.6	5.1	5.6	4.3	2.1	0

The range in elevation is from 3,900 to 4,700 feet while the greatest distance between stations is 6.6 miles. Generally speaking, elevation appears to play the most important rôle in determining the amount of rainfall recorded; however, there are many instances where it has very evidently not been the prime factor. Location of the stations with respect to the highest part of the Santa Rita Mountains undoubtedly has an influence though observations have indicated that it is very erratic. Explanation of the variations would require records covering a much longer period of time and the most important feature at the present time is that we realize the possible extent of rainfall variation in connection with our range improvement and range maintenance studies. Years of plentiful rainfall may minimize the significance of these variations somewhat, but in average or below average years there is every indication that they are a most important factor in the interpretation of results obtained in our studies of the vegetation. The variation of over 4 inches between Forest and Florida stations in 1929 was perhaps relatively insignificant but the variation of almost 2½ inches in 1925 (with total rainfall roughly a third of that which occurred in 1929) unquestionably exerted a profound influence upon both density and height growth of vegetation. The total amount of rainfall for any given season is only a small part of the story since its distribution throughout the period is equally as important and can only be determined by actual measurements. * * *

A few tropical cyclones cross the plateau of Mexico.[2]—It is the rather general belief that tropical cyclones can not cross high hills or mountains. The author of this article shows rather conclusively that it is possible to trace the progress of tropical cyclones across the Mexican central plateau. Following are the dates of crossing during the period 1921–1929:

I. Sept. 19–27, 1921.
II. Sept. 12–20, 1922.
III. Oct. 10–19, 1923.
IV. Sept. 7–17, 1924.
V. Sept. 15–22, 1925.
VI. Nov. 10–14, 1925.
VII. Sept. 26–29, 1926.
VIII. Sept. 5–11, 1927.
IX. Sept. 12–25, 1928.
X. Sept. 14–22, 1929.

The tracks of each of the above-mentioned have been charted and the discussion of them is rather full.—*A. J. H.*

Mud shower in North Carolina.—Mr. Paul Hess, in charge of the Weather Bureau station at Wilmington, N. C., sends us a clipping describing a shower of mud that fell at Edenton, N. C., on April 7, 1930. The fall was light, only sufficient to give a speckled appearance to objects on which it fell.

Showers are occasionally reported in which more or less dust is mixed with the rain and sometimes the dust fall is not attended by rain.[3] Showers in which organic matter is found are sometimes reported, see for example the article by W. L. McAtee on Showers of Organic Matter, May 1917, REVIEW.

In January, 1895, a very general dust fall was reported from Indiana and neighboring States, it fell on a snow cover and it was therefore an easy matter to obtain samples, of which more than 100 were collected, some of which were analyzed. The analysis showed a silt content of fully 96 per cent, the remaining 4 per cent being made up of organic matter; some samples being richer than others in organic content and the silt being also finer in some samples than in others.

The light soil of the Plains States is easily raised, carried by strong winds and deposited many miles from the place of origin; the very finest portions of the silt are generally supposed to descend only in fog, rain, or snow, and quite likely the mud rain at Edenton was caused in a like manner.—A. J. H.

Meteorological summary for Chile, April, 1930 (by J. Bustos Navarrete, Observatorio del Salto, Santiago, Chile).—

[2] Rafael Lucio in Revista de Meteorologia Y Aerologia, Vol. 1, No. 6 pp. 114–128.
[3] Cf. this REVIEW, 58: 65.

With April came the beginning of the rainy season in the central region of Chile. The atmospheric circulation over the Pacific showed moderate intensity, but the mean path of the depressions was shifted more to the north.

The depressions of greatest importance were charted as follows: 12th to 17th, crossing the extreme south and causing unsettled weather with general rains in the south; and 24th to 26th, affecting conditions over the entire central region, with rain and high wind from Chiloe to Coquimbo. Snow fell to moderate depths in the cordillera and a temperature of 19° F. was recorded at Portillo (10,500 feet).

Periods of fine weather and fall in temperature accompanied the anticyclones of the periods 1st to 8th, 21st to 24th, and 28th to 30th, all moving from southern Chile, latitude 40° to 45° S., toward northern Argentina.—*Translated by W. W. R.*

Meteorological station at Portillo, Chile.—In April the Observatorio del Salto, Santiago, Chile, installed a new meteorological station at Portillo in the cordillera of the Andes at an elevation of 3,000 meters (9,840 feet). This station is equipped with instruments for the automatic recording of pressure, temperature, humidity, direction and force of wind, and precipitation.—*J. B. N.*

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING MAY, 1930

By HERBERT H. KIMBALL, Solar Radiation Investigations

For reference to descriptions of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this volume of the REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged slightly above the normal intensity for May at Washington and Lincoln, and close to normal at Madison.

Table 2 shows an excess in the total radiation received on a horizontal surface at Washington, New York, and Chicago, a deficiency at Lincoln, Twin Falls, and Fresno, and close to the May normal at Madison.

Skylight polarization measurements obtained on 7 days at Washington give a mean of 53 per cent and a maximum of 62 per cent on the 29th. At Madison measurements obtained on 6 days give a mean of 55 per cent with a maximum of 63 per cent on the 2d. These are close to the corresponding averages for May at Washington and slightly below at Madison.

TABLE 1.—*Solar radiation intensities during May, 1930*

[Gram-calories per minute per square centimeter of normal surface

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass, A. M.					Air mass, P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 3	4.75	0.69	0.79	0.98	1.19	1.33	0.86				6.02
May 5	5.79	0.50	0.61	0.76	0.98	1.22					7.57
May 7	9.83				0.88	1.20					12.68
May 9	9.83					1.27					6.76
May 10	5.79				0.97	1.28	1.02				6.50
May 13	10.59				1.07	1.26					7.57
May 16	7.29			0.91	1.11						7.29
May 20	8.48				0.76						10.59
May 23	13.13				0.97	1.30					12.24
May 27	4.75		0.92	0.92	1.08	1.38					4.75
May 28	7.57			1.01	1.15	1.47					10.59
May 29	5.36			0.93	1.08						5.36
Means		(0.60)	(0.77)	0.92	1.04	1.30	(0.94)				
Departures		−0.04	+0.06	+0.10	+0.05	+0.01	−0.04				

Madison, Wis.

Date	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon
May 2	6.76				1.22	1.41					5.16
May 3	6.02			0.99	1.14	1.37					5.79
May 5	13.13					1.33					11.38
May 6	14.10				0.97						15.11
May 8	8.18					1.26					4.83
May 17	3.99				1.11	1.23					3.30
May 24	4.17				1.18	1.39					4.57
May 26	4.95					1.26	0.96				5.79
May 31	5.36					1.40					5.56
Means				(0.99)	1.12	1.33	(0.98)				
Departures				+0.04	+0.01	−0.02	−0.07				

Lincoln, Nebr.

Date	8 a.m.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Noon
May 2	8.48		0.87	1.06	1.20	1.43	1.18	1.00	0.86	0.75	12.24
May 3	11.38		0.84	1.00	1.15	1.34					14.10
May 4	14.10					1.41	1.16	0.99	0.85	0.74	12.68
May 8	8.18				1.18	1.35					10.97
May 24	6.27			0.82	1.10	1.45	1.14	0.97	0.81		6.50
May 25	7.29		0.70	0.88	1.08	1.35	1.03	0.84	0.68		7.29
May 27	8.48			0.80	0.96						11.81
May 30	6.27						1.20	1.04	0.93	0.78	5.79
May 31	7.04			1.06	1.24						10.59
Means			0.80	0.94	1.13	1.39	1.14	0.97	0.83	0.76	
Departures			−0.01	±0.00	+0.01	+0.01	+0.03	+0.03	+0.03	+0.04	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning	Average daily totals									
	Washington	Madison	Lincoln	Chicago	New York	Pittsburgh	Gainesville	Twin Falls	Fresno	La Jolla
1930										
Apr. 30	542	471	469	473	456	438	649	498	493	290
May 7	537	389	422	462	479	510	739	480	686	532
May 14	405	356	371	289	219	263	714	496	599	386
May 21	587	496	564	402	378	515	621	711	735	509
May 28	654	636	564	486	415	465	*626	#707	769	509
	Departures from weekly normals									
Apr. 30	+86	+18	−5	+104	+86			−75	−133	
May 7	+75	−75	−60	+78	+111			−122	+40	
May 14	−55	−112	−138	−91	−149			−158	−57	
May 21	+98	+11	+37	+2	−11			+6	+40	
May 28	+145	+142	+43	+64	+5			+22	+8	
Accumulated departure on June 3, 1930	+2,072	−224	−1,351	+3,388	+49			−28	−1,513	

* 5-day mean. # 6-day mean.

TABLE 2.—*Total solar radiation (direct diffuse) received on a horizontal surface*—Continued

LATE REPORTS, MARCH AND APRIL, 1930

NEW YORK

Average daily totals

1930		1930	
Feb. 26	226	Apr. 2	338
Mar. 5	195	Apr. 9	320
Mar. 12	280	Apr. 16	226
Mar. 19	360	Apr. 23	439
Mar. 26	292		

Departures from weekly normals

Feb. 26	−4	Apr. 2	+27
Mar. 5	−65	Apr. 9	−7
Mar. 12	+15	Apr. 16	−104
Mar. 19	+92	Apr. 23	+87
Mar. 26	+13		
Accumulated departure on Apr. 1	−224	Accumulated departure on Apr. 29	−245

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. N., Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Mount Wilson and Perkins observatories. The differences of longitude are measured from central meridian positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Longitude	Latitude	Area: Spot	Area: Group	Total area for each day
1930	h m	°	°	°			
May 1 (Naval Observatory).	10 55	−6.0	345.0	+11.0		170	
		+27.0	18.0	−8.5		12	
		+33.0	24.0	+13.0		123	
		+40.5	31.5	−7.0	185		490
May 2 (Naval Observatory).	11 14	+8.0	345.6	+11.5		154	
		+41.0	18.6	−8.5		12	
		+46.5	24.1	+12.5		62	
		+54.5	32.1	−7.0	185		413
May 3 (Naval Observatory).	10 55	−51.0	273.6	+17.5		30	
		+20.5	345.1	+12.0		123	
		+60.0	24.6	+12.5		77	
		+67.5	32.1	−6.5	185		416
May 4 (Naval Observatory).	11 5	−36.0	275.3	+16.5		77	
		+32.0	343.3	+12.0		108	
		+81.0	32.3	−7.0	139		324
May 5 (Naval Observatory).	10 53	−22.0	276.2	+17.0		247	
		+44.0	342.2	+13.0		37	284
May 6 (Naval Observatory).	10 52	−9.0	276.0	+17.5		355	
		+57.5	342.5	+14.0	15		370
May 7 (Naval Observatory).	10 59	+4.5	276.2	+17.5		463	463
May 8 (Naval Observatory).	11 1	+17.5	275.9	+17.0		509	509
May 9 (Naval Observatory).	10 52	+31.5	276.8	+17.0		463	463
May 10 (Naval Observatory).	10 46	+45.5	277.6	+16.5		463	463
May 11 (Naval Observatory).	11 12	−11.5	207.2	+2.0		19	
		+60.0	278.7	+17.0		386	405
May 12 (Yerkes).	15 32	+4.0	207.1	+2.5		181	
		+70.0	273.1	+16.5	100		
		+78.0	281.1	+15.5	433		714
May 13 (Naval Observatory).	11 5	+15.5	207.8	+2.5		93	
		+71.5	263.8	+18.5		31	124
May 14 (Mount Wilson).	12 15	+30.0	208.4	+2.0		105	105
May 15 (Naval Observatory).	10 55	−8.5	157.4	−6.0		37	
		+13.0	178.9	+15.5		9	
		+42.5	208.4	+3.0		46	92
May 16 (Naval Observatory).	10 55	−72.5	80.2	−11.0		123	
		+7.0	159.7	−6.0		46	
		+56.0	208.7	+3.0		62	231
May 17 (Naval Observatory).	10 53	−58.5	81.0	−11.0		154	
		+23.5	163.0	−6.0	9		163
May 18 (Mount Wilson).	13 0	−46.0	79.1	−11.0		201	
		+40.0	165.1	−7.0	8		209

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1930	h	m	°	°	°			
May 19 (Perkins Observatory).	16	28	−73.3	36.3	−7.0	109		
			−29.9	79.7	−11.8		232	341
May 20 (Naval Observatory).	10	51	−62.5	37.3	−6.0	77		
			−18.5	81.3	−10.5		216	293
May 21 (Naval Observatory).	10	55	−48.5	38.0	−5.5	46		
			−5.0	81.5	−10.0		247	293
May 22 (Naval Observatory).	10	47	−36.0	37.4	−6.0	62		
			+8.0	81.4	−10.0		231	293
May 23 (Naval Observatory).	11	5	−72.0	348.0	+14.5		108	
			−59.0	1.0	−11.0		15	
			−30.0	30.0	+19.5		9	
			−22.5	37.5	−6.0	34		
			+22.0	82.0	−10.0		185	
			+45.0	105.0	+26.5		43	394
May 24 (Naval Observatory).	11	8	−59.0	347.7	+13.5		77	
			−45.0	1.7	−11.0		12	
			−14.0	32.7	+19.5	3		
			−9.5	37.2	−6.0	34		
			+36.5	83.2	−9.5		93	
			+56.0	102.7	+27.0	6		225
May 25 (Naval Observatory).	11	5	−46.0	347.5	+13.5		46	
			−31.5	2.0	−12.0	6		
			−2.0	31.5	+19.5		46	
			+2.0	85.5	+25.5		9	
			+4.0	37.5	−6.5	28		
			+50.5	84.0	−9.0		108	243
May 26 (Naval Observatory).	10	50	−32.5	347.9	+13.5		46	
			+11.0	31.4	+19.5		71	
			+16.5	36.9	−6.5	25		
			+64.0	84.4	−9.5	93		235
May 27 (Naval Observatory).	10	54	−24.0	343.2	−1.0		6	
			−20.5	346.7	+12.5		6	
			+25.5	32.7	+19.5		108	
			+30.0	37.2	−6.5	9		
			+79.0	86.2	−9.5	77		206
May 28 (Naval Observatory).	13	8	−73.5	279.2	+16.5	139		
			−14.0	338.7	+13.0		77	
			+40.0	32.7	+19.5		68	
			+44.0	36.7	−6.5	6		290
May 29 (Naval Observatory).	11	21	−60.5	280.0	+16.5	139		
			−20.0	320.5	−2.0		6	
			+0.5	341.0	+12.5		62	
			+52.5	33.0	+20.0		123	
			+58.0	38.5	−7.0		15	345

Positions and areas of sun spots—Continued

Date	Eastern standard civil time		Heliographic			Area		Total area for each day
			Diff. long.	Longitude	Latitude	Spot	Group	
1930	h	m	°	°	°			
May 30 (Naval Observatory).	10	46	−48.0	279.5	+16.5	154		
			−6.5	321.0	−2.5		15	
			+15.0	342.5	+12.0	12		
			+66.0	33.5	+20.0		170	
			+70.0	37.5	−6.5	6		357
May 31 (Naval Observatory).	11	6	−34.5	279.6	+17.0	154		
			+6.5	320.6	−2.5	2		
			+29.5	343.6	+12.0	12		
			+85.0	39.1	+20.0		231	399
Mean daily area for May.								327

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR MAY, 1930 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

May, 1930	Relative numbers	May, 1930	Relative numbers	May, 1930	Relative numbers
1	52	11	*Mc* 22	21	31
2	*a* 52	12	25	22	*b* 33
3	50	13		23	*d* 45?
4	41	14		24	67
5	*Ec* 30	15	32	25	46
6	37	16	*d* 41	26	*Mc* 43
7	*b* 25	17	35	27	56
8	26	18	25	28	*d* 38
9	23	19	31	29	*a* 52
10	19	20	39	30	48
				31	35

Mean, 29 days=37.9.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

The free-air temperatures were above normal at Due West and Royal Center and in the upper levels at Ellendale. At Broken Arrow and Groesbeck and in the lower levels at Ellendale they were below normal. In all cases the departures were small.

The free-air relative humidities were above normal in the lower levels at all of the stations and were below normal in the upper levels.

The free-air vapor pressures were below normal at Broken Arrow but were mostly above normal at the other aerological stations.

In the lower levels the resultant winds were northwesterly on the Pacific coast and southerly in the eastern part of the country. The resultant winds changed to westerly at the 2,000-meter level and remained westerly above this level.

Airplane observations made at Hampton Roads, Va., have been included in Table 2.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during May, 1930*

TEMPERATURE (° C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	18.6	−1.1	21.6	+1.1	11.6	−1.5	20.4	−2.1	16.5	+0.4
500	17.6	−0.2	19.2	+1.3	11.1	−1.6	19.1	−0.7	14.6	+1.2
1,000	15.1	−0.5	16.4	+1.5	8.0	−1.5	16.5	−0.9	11.6	+1.4
1,500	12.5	−0.9	13.4	+1.5	6.2	−0.4	14.8	−0.8	8.6	+1.2
2,000	10.3	−0.5	9.9	+0.9	4.5	+0.9	12.5	−0.9	5.7	+0.7
2,500	7.9	−0.1	6.7	+0.5	2.2	+1.5	9.5	−1.2	3.0	+0.4
3,000	5.4	+0.5	3.7	+0.5	−0.7	+1.4	5.7	−2.0	0.7	+0.9
4,000	−1.8	−0.5	−2.5	+0.5	−7.5	+0.5			−5.0	+1.3
5,000			−8.4	+1.4	−13.5	+0.6			−11.8	+0.3

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Broken Arrow Mean	Departure	Due West Mean	Departure	Ellendale Mean	Departure	Groesbeck Mean	Departure	Royal Center Mean	Departure
Surface	76	+6	66	+2	66	+6	86	+14	70	+6
500	70	+1	66	+1	66	+6	78	+5	69	+5
1,000	68	+1	65	0	66	+7	76	+7	69	+6
1,500	60	−2	63	−2	62	+2	65	+7	68	+7
2,000	47	−12	62	−1	55	−5	52	+3	63	+6
2,500	41	−15	59	−1	55	−4	44	−1	56	+5
3,000	36	−18	55	−2	55	−2	50	+5	49	+2
4,000	26	−29	51	−3	52	−1			44	−2
5,000			49	−3	46	−5			44	−2

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during May, 1930*—Continued

VAPOR PRESSURE (*mb*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	16.42	−0.01	16.98	+1.48	9.06	−0.02	20.89	+1.23	13.46	+1.58
500	14.33	−0.05	14.71	+1.21	8.84	+0.01	17.20	+0.09	11.99	+1.88
1,000	11.85	+0.02	12.44	+1.19	7.09	+0.04	14.23	+0.47	9.95	+1.74
1,500	8.91	−0.41	9.74	+0.47	5.92	+0.03	10.86	+0.76	7.80	+1.31
2,000	5.95	−1.46	7.69	+0.33	4.80	+0.03	7.46	+0.14	5.90	+0.79
2,500	4.30	−1.47	5.80	+0.01	4.19	+0.44	5.23	−0.49	4.11	+0.35
3,000	3.29	−1.29	4.53	+0.04	3.57	+0.66	5.16	+0.43	2.88	+0.18
4,000	1.07	−2.00	3.45	+0.45	2.20	+0.55			1.71	+0.19
5,000			3.19	+1.16	1.56	+0.63			1.06	+0.28

TABLE 2.—*Free-air data obtained at naval air stations during May, 1930*

Altitude (meters) m. s. l.	Temperature (° C.)					Relative Humidity (%)				
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.
Surface	20.1	22.4	18.8	13.3	20.3	64	86	65	68	59
500	18.0	21.2	14.7	9.6	17.5	56	74	72	73	55
1,000	15.4	18.9	13.6	6.4	14.9	53	66	62	71	54
2,000	9.1	13.3	10.3	1.1	9.0	54	58	39	68	56
3,000	2.5	8.3	4.9	−4.6	3.4	58	38	33	54	49
4,000	−3.2			−11.1	0.9	59			62	34
5,000				−17.1					56	

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during May, 1930*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°	
Surface	S 19 E	2.1	S 21 W	1.8	N 88 W	2.2	N 9 E	0.3	N 43 W	1.5
500	S 2 W	5.6	S 68 W	3.2			S 78 W	2.0	N 60 W	1.8
1,000	S 27 W	7.0	N 76 W	6.0			N 82 W	3.3	S 82 W	3.7
1,500	S 59 W	5.1	N 59 W	9.8			S 88 W	3.3	S 73 W	4.0
2,000	S 63 W	7.1	N 59 W	10.7	S 89 W	3.6	S 83 W	4.2	S 81 W	5.4
2,500	S 80 W	6.0	N 55 W	10.8	N 88 W	6.6	N 85 W	4.6	S 80 W	5.3
3,000	S 80 W	5.5	N 38 W	12.8	S 84 W	7.7	N 86 W	5.6	S 87 W	5.6
4,000	N 62 W	6.4			S 82 W	8.7	N 79 W	7.5	N 83 W	7.7
5,000	N 68 W	6.5			S 78 W	7.2	N 75 W	8.1	N 84 W	8.9

Altitude (meters) m. s. l.	Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°	
Surface	S 35 E	1.6	N 84 E	0.3			S 63 E	2.3	N 63 W	1.1
500	S 16 E	4.8					S 55 E	5.2	S 75 E	1.7
1,000	S 1 W	5.0	S 65 W	1.3			S 42 E	4.4	S 71 E	0.9
1,500	S 5 W	1.1	S 77 W	4.1			S 45 E	2.5	N 59 W	1.7
2,000	N 72 W	1.5	N 75 W	5.1			S 24 E	1.4	N 70 W	2.5
2,500	N 66 W	3.6	N 61 W	5.2			S 53 E	1.2	N 89 W	2.9
3,000	N 19 E	1.1	N 80 W	5.9			S 61 E	1.1	N 89 W	3.8
4,000	S 83 E	0.8	S 86 W	8.7			N 53 W	1.1	S 88 W	6.8
5,000	S 29 E	0.5	N 61 W	8.6			N 70 W	3.1		

Altitude (meters) m. s. l.	Medford, Oreg. (446 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°	
Surface	N 72 W	0.5	S 56 E	1.1	N 75 W	1.1	S 55 E	1.0	S 7 W	1.6
500	N 84 W	1.1.	S 50 W	2.5	S 58 E	4.1	S 21 W	2.3	S 51 W	5.9
1,000	N 53 W	1.8	S 64 W	4.6	S 37 E	4.7	S 50 W	4.8	S 70 W	7.9
1,500	N 46 W	0.5	S 72 W	5.5	S 20 E	4.4	S 71 W	4.6	S 71 W	8.4
2,000	S 51 W	1.1	S 83 W	5.4	S 10 W	4.0	N 85 W	6.3	S 72 W	8.2
2,500	S 43 W	3.3	S 64 W	5.1	S 54 W	2.3	N 84 W	7.8	S 88 W	9.3
3,000	S 67 W	2.7	W	5.4	S 74 W	3.5	N 86 W	9.8	N 85 W	10.3
4,000	N 32 W	4.5	S 63 W	4.6	N 84 W	5.9	N 83 W	10.3	N 69 W	10.7
5,000					N 81 W	5.9	N 61 W	9.3	N 53 W	10.1

Altitude (meters) m. s. l.	Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (5 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°	
Surface	S 30 E	3.2	S 80 W	2.7	S 85 E	0.3	S 41 E	0.7	N 68 W	1.1
500			N 74 W	3.5	S 5 E	1.2	S 9 W	2.6	N 53 W	5.5
1,000			N 45 W	5.9	S 87 W	3.5	S 20 W	2.9	N 57 W	5.6
1,500	S 15 E	5.4	N 32 W	5.9	N 74 W	5.4	N 44 W	0.5	N 56 W	7.4
2,000	S 1 W	4.1	N 52 W	5.0	N 70 W	5.5	N 2 W	1.4	N 69 W	8.1
2,500	S 19 W	4.2	N 58 W	7.2	N 70 W	6.5	N 51 W	2.3	N 81 W	9.3
3,000	S 32 W	4.6			N 59 W	6.0	S 13 W	4.4	N 86 W	11.3
4,000	S 67 W	5.1			N 53 W	9.0				
5,000	S 78 W	4.5								

TABLE 4.—*Observations by means of kites, captive and limited—height sounding balloons, during May, 1930*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,518	3,304	3,181	2,096	3,388
Maximum altitude (meters), m. s. l., reached and date	[1] 4,126	[2] 5,789	[3] 6,044	[4] 3,378	[5] 5,778
Number of flights made	31	28	35	30	31
Number of days on which flights were made	30	28	30	28	31

[1] 3d. [2] 31st. [3] 19th. [4] 9th. [5] 30th.

In addition to the above there were approximately 125 pilot balloon observations made daily at 53 weather bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

The temperature during the first two weeks of May was abnormally high in the eastern half of the country, while in the western half it was generally below the normal. However, during the remainder of the month, cool weather persisted throughout most sections with some very low temperatures for the season in the Eastern and Central States.

The precipitation for the month was below the normal in most regions east of the Mississippi River. In the Ohio Valley and some portions of the Atlantic Coast States, less than half the usual amounts were reported, while over a belt extending from the southern Appalachian Mountains to eastern Oklahoma and Texas more than twice the normal for the month was received, as was also the case in some central Rocky Mountain and southwestern sections, but the central Rio Grande Valley and much of the northern Plains and central Pacific coast areas were generally dry.

PRESSURE AND WINDS

The month opened with a low-pressure area north of the Red River Valley, with moderate precipitation and thunderstorms over much of the northern and central Great Plains and northeastward to the upper Lake region. Elsewhere generally fair weather prevailed, except local rains were received in southern California and extreme southern Florida. During the next three days, this low-pressure area moved southeasterly to the upper Lake region and easterly out the St. Lawrence Valley, and was accompanied by moderate precipitation in the great central valleys and to the northeast with many thunderstorms.

On the 3d, low-pressure areas moved in from the far Northwest and far Southwest, with light precipitation over most of the Pacific and Plateau regions, and by the next day the Southwest low area had merged with the one from the Northwest, which moved slowly eastward and was accompanied by light precipitation over much of the Plateau, Rocky Mountain and western Great Plains regions, with a few rather heavy thundershowers in the Southwest. This low area moved slowly over the upper Lake region and off the northeast coast by the 7th, and was accompanied by light precipitation.

A low-pressure area appeared in western Texas on the 6th, and moved to southwestern Iowa by the 7th, to central Minnesota by the 8th, and to the north of eastern Montana by the 10th, where it dissipated. It was accompanied in northern and central Texas by local high winds, tornadoes, rain, and hail. About 80 persons were killed and property of various kinds was materially damaged, while in portions of the Missouri and upper Mississippi Valleys moderate to heavy precipitation was received. During the first decade, little precipitation was received in most of the East and South, except occasional local rains in a few localities, while in the Pacific States moderate precipitation occurred on the 3d and 4th and again on the 6th and 7th.

On the 10th of the month, a low-pressure area developed in the Southwest, moved northeast and thence north to eastern South Dakota by the 13th, and thence easterly and out the St. Lawrence Valley by the 18th. This low area was accompanied by rather widespread precipitation, with some heavy falls in the Missouri and upper Mississippi Valleys, and also in some portions of the Atlantic and Gulf States. On the 15th, a low-pressure area developed in the Southwest, and moved northeasterly to the Ohio Valley by the 17th, and off the northeast coast by the 21st. Widespread precipitation, in places heavy, accompanied this low, and extended to the Gulf and Atlantic coasts on the 18th and 20th.

At the beginning of the third decade, a low-pressure area moved in from the Northwest and during the 21st and 22d overspread much of the Plateau, Rocky Mountain, and western Great Plains regions, and during the 23d and 24th moved over the Great Lakes and out the St. Lawrence Valley. Moderate to heavy precipitation fell in portions of the Rocky Mountains, the Missouri and upper Mississippi Valleys and Lake region. This low was followed by a rather extensive high area and generally fair weather, which continued until after the middle of the decade. During the remainder of the month the pressure was relatively low over much of the country, with moderate precipitation in many localities, but on the 29th and 30th some heavy rains occurred in portions of the Gulf and South Atlantic States. The month closed with high pressure and fair weather over the eastern half of the country, except light local precipitation was received in portions of the New England States, the Florida peninsula, and the Rio Grande Valley, while low pressure prevailed in the Rocky Mountain and Plateau regions, with light precipitation in the northern portions of the Plateau and Pacific States.

Chart VI and the insets of Charts II and III present the usual information as to the mean pressure of the month.

Severe local storms were reported in considerable number, as usually happens at this season of the year. The customary table of these storms may be found at the end of this section.

TEMPERATURE

The warm weather which had set in just before April ended continued over the eastern half and much of the Plains during the first decade and the early part of the middle decade. The interior portions of the North and Middle Atlantic States, the Ohio Valley, the Lake region, and the greater part of the upper Mississippi Valley had temperatures much above normal practically throughout this period. However, the West was experiencing cool weather for the most part, especially about the 5th to 10th.

The week ending the 20th brought a marked change in the temperature situation, for it was considerably cooler than normal in the north-central portion, the central valleys, and in substantially all parts of the Lake region, the Plains, and the middle and southern Rocky Mountain region. However, most of the Atlantic and Gulf States were warmer than normal, likewise the northern Plateau and the interior of the North Pacific States.

The final decade of May was a period of less-marked departures from normal temperature conditions, except that the last four days brought decidedly cool weather to the north-central and northeastern portions of the country and as far south as the southern Appalachians. This decade was mainly cooler than normal in the middle and southern Plains and everywhere to eastward and northeastward, likewise in the southern and middle

Plateau and the extreme Northwest; but it was somewhat warmer than normal over most of the middle and upper Missouri Valley and the northern Rocky Mountain region.

The month averaged warmer than normal almost everywhere east of the Mississippi River, and usually by 3° to 5° from southern New England to eastern Virginia. Portions of northwestern New York and of Tennessee averaged a trifle cooler than normal. West of the Mississippi River, much of Minnesota and of the west Gulf region, also a part of Montana, averaged warmer than normal; but otherwise the month averaged cooler than normal, particularly in North Dakota, the southern Plateau region, Nevada, and the interior of California. A number of points in Arizona or districts adjacent thereto had deficiencies of 4° or more per day.

The highest temperatures occurred usually about the 5th to 9th in the Lake region, the Ohio Valley, and to eastward, but about the 17th to 19th in parts of the South Atlantic States. For most of the Southwest the hottest weather came about the 19th to 21st, but the Northwest, the middle Plains, and the lower Mississippi Valley scored their highest marks about the 26th to 28th. The highest reading reported anywhere was 110° in southeastern California on the 19th.

The lowest readings occurred usually about the 6th to 12th in the Pacific States, the Southwest, and the middle Plateau and Mountain sections, usually the 16th to 18th in the northern and middle Plains and the upper Mississippi Valley, during the final week of the month in the Lake region, the central valleys, and to eastward and southeastward, except in a few Atlantic States on the 3d or 4th, or else about the 10th to 12th. The very lowest was 2° above zero, at an elevated station in Colorado, on the 6th.

PRECIPITATION

The amounts measured during May were noticeably greater, for most of the country, than the amounts of the earlier spring months had been. Out of 48 States, 25 averaged above the normal May quantities, only five below 60 per cent of normal, and none below 40 per cent of normal. Yet the distribution of the May precipitation was not good. Excessively large amounts were received in the lower Mississippi Valley, chiefly between the 5th and the 20th, while most of the Florida peninsula had very heavy downpours just before the month ended.

Compared with normal amounts the western half of the country received excesses more widely than the eastern half. A large proportion of the districts along and near the Mexican border had much more than the normal precipitation, and this was the case in Nevada likewise and most districts adjacent thereto. The drainage area of the Platte River was marked by excessive rains; also northeastern Texas. Considerable shortages, however, were noted in Montana, western North Dakota, and the Black Hills region, also in central New Mexico and a few other districts.

In the eastern half, decidedly less rain than normal was reported from southern Alabama and western Florida, and thence northeastward to Maryland and New Jersey, and from these States westward over all the upper Ohio Valley and most of the lower portion besides, also over eastern Missouri and the districts adjacent to Lake Michigan. Slightly more than normal was received over most of Minnesota and eastern Iowa, central and eastern New York, and northern New England. At the close of the first paragraph of this section, two areas of decidedly excessive falls were mentioned; in the former is located the station reporting the greatest amount for May, 1930, anywhere in the country, Moorhead, Miss., where 19.70 inches fell.

SNOWFALL

East of the Plains the snowfall was of small account in those Northern States which usually record some in May. In the West, however, many of the southern and central Mountain and Plateau States received greater snowfall than usual, Nevada and Arizona showing larger averages than in any previous May. At Phoenix, where even the winters pass nearly every time without a single flake of snow, there was a brief flurry on the morning of May 9.

RELATIVE HUMIDITY

In the central and southern portions of the Plateau and Rocky Mountain regions, much of the Great Plains, and the west Gulf region, the percentages of relative humidity were nearly everywhere above normal, but generally along the Pacific and in the northern portions of the Plateau and Rocky Mountain regions, and east of the Mississippi River, except a few stations in the Lake regions, the New England States, and the southern Allegheny region, humidity percentages were less than normal, though the negative departures were in most cases not large.

SEVERE LOCAL STORMS, MAY, 1930

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards [1])	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Homer, Nebr.	1	5:10 p. m.	100		$1,500	Tornado	Small farm buildings damaged over path 5 miles long.	Official, U. S. Weather Bureau
Bancroft, Nebr.	1	5:15 p. m.	5-40		40,000	do	Buildings on 6 farms demolished; path 7 miles	Do.
Mound City to Maitland, Mo.	1	5:30 p. m.	50-100			do	11 farms devastated	Do.
White Cloud, Kans., to Napier, Mo.	1	do				do	Buildings on 2 farms demolished; path 4 miles	Do.
Clay, Fayette, Harrison, Mitchell, Woodbury, Cerro Gordo, and Hamilton Counties, Iowa.	1	5:30-8 p. m.			48,400	9 tornadoes	No details of damage reported; some storms accompanied by hail.	Do.
Newton, Kans. (near)	1	5:40 p m.			6,000	Tornado	Farm buildings damaged; livestock killed; path 8 miles.	Do.
Wichita, Kans. (20 miles north of).	1	5:50 p. m.				do	No damage reported	Do.
Wayne, Lucas, and Monroe Counties, Iowa.	1	6-8:15 p. m.		1	144,200	3 tornadoes	Extensive damage to farm property and crops; 25 persons injured.	Do.
Dunavant, Kans., to Smithville, Mo.	1	6:15 p. m.	33-440	2	500,000	Tornado	About 50 farms damaged; 20 persons injured	Do.

[1] "Mi." signifies miles instead of yards.

Severe local storms, May, 1930—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Fillmore to Bolckow, Mo.	1	6:20 p. m.				Tornado	A number of homes damaged or totally destroyed; some loss of machinery and livestock.	Official, U. S. Weather Bureau.
Tekamah, Nebr.	1	6:30 p. m.	333	4	$250,000	do	Buildings on a number of farms demolished; 15 dwellings in Tekamah wrecked; about 35 persons injured; path 15 miles long.	Do.
Rosendale, to Union Star, Mo.	1	6:30–7:30 p. m.	440–1,760		[1] 450,000	do	Much destruction to property over path 10 miles long.	Do.
Norwich, Kans. (5 miles south of).	1	7 p. m.	100		2,500	do	Damage chiefly to farm buildings; path one-half mile long.	Do.
Tahoka, Tex.	1	do	1.5 mi.		15,000	Hail	Chief damage to buildings	Do.
Conway, Kans. (near)	1	7:30 p. m.	75		4,000	Tornado	Damage chiefly at Elwell, where grain elevator was wrecked; path 8.5 miles.	Do.
Trempealeau County, Wis., across State to Lake Michigan.	1	7:30–8 p. m.		2	1,096,000	Wind, 4 small tornadoes, and hail.	Marked loss to farm and town buildings and overhead wire systems; livestock and 15 persons injured; little crop damage.	Do.
Norborne, Mo. (10 miles northwest of).	1	9 p. m.	75–100	6	350,000	Tornado	46 farmhouses destroyed; 20 persons injured	Do.
Garden Prairie, Ill. (near)	1	10 p. m.	880		25,000	do	Character of damage not reported; path 15 miles long.	Do.
Decatur, Ill	1	11:50 p. m.	200		100,000	do	No details of damage; path 1 mile long	Do.
Illinois (northern, central and west-central counties).	1	P. m.		1	150,000	Wind and thunderstorms.	Extensive property and crop damage; some damage by hail at Rockford.	Do.
Iowa (22 counties)	1					Hail and wind	Considerable damage to property throughout State.	Do.
Pipestone, Minn. (12 miles northwest of).	1					Tornado	Rural school damaged	Journal (Sioux City, Iowa).
Chicago, Ill. (Beverly Hills district).	2	12:27 a. m.			25,000	Wind	Many buildings damaged; trees broken; several persons injured; some damage by fire.	Official, U. S. Weather Bureau.
Michigan (west-central)	2	2–4 a. m.			1,200,000	6 tornadoes	Many farm buildings, wood lots, and orchards leveled; livestock killed; greatest damage in and near Grand Rapids.	Do.
Gober, Tex.	2	12:30 p. m.	1,760			Hail	Cotton and corn badly damaged	Do.
Tuscola and Ovalo, Tex.	2	4:30 p. m.	1,760			do	Orchards, windows, and roofs damaged	Do.
Floyd County, Iowa	2	10 p. m.			8,500	Wind	Details of damage not reported	Do.
Waurika, Okla. (near)	3	5 p. m.			1,000	Hail	Crops and gardens damaged	Do.
Eagle Pass, Tex.	3	5:30 p. m.	5 mi.		50,000	do	Crops, roofs, windows, and auto tops damaged	Do.
Milan, Kans. (2 miles east of).	3	P. m.			1,000	Wind	A farmhouse and other buildings wrecked	Do.
Caddo County, Okla.	5	A. m.			6,000	Hail	Damage chiefly to crops; path 8 miles long	Do.
Cotton County, Okla.	5	2 p. m.	3 mi.		10,000	do	Crops badly injured; path 7 miles long	Do.
Ellinwood, Kans. (east of)	5	3:45 p. m.	440		2,000	Tornado	Farm property damaged; path 4 miles	Do.
Adams County, Nebr. (northwestern).	5	4 p. m.	200		9,000	do	Farm buildings damaged over path several miles long.	Do.
Turon to Langdon, Kans.	5	do	880		8,000	Tornado and hail	Damage chiefly to farm property; several persons injured; path 15 miles.	Do.
Lorraine (near) to Ellsworth (near), Kans.	5	4:20 p. m.	500		30,000	Tornado	Damage chiefly to farm property; path 19 miles.	Do.
Ellinwood (near) to Chase (near), Kans.	5	5:15 p. m.	880		300,000	do	Farm property in path totally destroyed; about 40 box cars blown from tracks; livestock killed; path 25 miles.	Do.
Antelope County, Nebr.	5	5:30 p. m.	55		12,000	do	Farm buildings wrecked; path 7 miles	Do.
Lincoln to Barnard, Kans.	5	6–6:30 p. m.	440		12,000	do	Farm buildings damaged path 10 miles	Do.
Clarke County, Iowa	5	7:30 p. m.			3,000	Tornado and hail	Character of damage nor reported; path 3 miles	Do.
Woodbury County, Iowa	5	do			6,000	Wind and hail	Character of damage not reported	Do.
Falun, Kans. (near)	5	9 p. m.				Tornadic wind	Minor property damage	Do.
Solomon (near) to Riley (near), Kans.	5	9:30–10 p. m.	440		100,000	Tornado	Extensive damage in farm area; 20 persons injured; path 50 miles long.	Do.
Decatur, Jones, and Taylor Counties, Iowa.	5	P. m.				Wind	Details not reported	Do.
Maywood, Ill	5		25–33		4,000	Tornado	Considerable damage over path 4 blocks long	Do.
Gage County, Nebr.	6	3–7 a. m.				High wind	Windmills and farm buildings wrecked	Do.
Austin, Tex.	6	10 a. m.				Wind	Buildings damaged; 3 persons injured	Do.
Decatur County, Iowa	6	11 a. m.			5,000	Tornado and hail	Character of damage not reported; path 5 miles	Do.
Abilene, Tex., and vicinity	6	11:49 a. m.			25,000	Wind	Buildings and crops damaged	Do.
Spur, Tex. (near)	6	Noon		1		do	Poorly constructed buildings damaged; 10 persons injured.	Do
Eastland, Tex.	6	12:20 p. m.			2,000	do	Houses and derricks damaged; 1 person injured	Do
Mahaska County, Iowa	6	12:25 p. m.			4,000	Tornado	Character of damage not reported; path 5 miles	Do
Poweshiek County, Iowa	6	2 p. m.			75,000	do	Character of damage not reported; path 12 miles; 2 persons injured.	Do
Oklahoma City, Okla., and vicinity.	6	2:30 p. m.	1,320		50,000	Wind	A few houses unroofed; garages damaged; oil derrick, smokestack and boiler blown down; path one-half mile.	Do.
San Antonio, Tex. (near)	6	3:15 p. m.	300	1	20,000	do	Airplane hangar damaged; 1 person injured	Do.
Bynum to Frost, Tex.	6	3:30 p. m.	400	38	2,000,000	Tornado	Everything in path destroyed	Do.
Ennis, Tex.	6	4 p. m.	220	3	100,000	do	Buildings and crops destroyed or damaged	Do.
Grant County, Wis. (east-central).	6	4 p. m.			2,000	Severe squall	Farm property damaged	Do.
Gonzales to Ottine, Tex.	6	4:30 p. m.	2 mi.	1	45,000	Wind	Buildings damaged; poultry and livestock killed; crops injured.	Do.
Kennedy to Nordheim, Tex.	6	4:45–5 p. m		36	127,000	Tornado	Buildings and crops damaged	Do.
Bronson, Tex. (near)	6	9:30 p. m.	200	2	11,000	do	Buildings, farm implements, and crops damaged; livestock injured.	Do.
Allamakee, Linn, Ringgold, Tama, and Delaware Counties, Iowa.	6	P. m.			14,500	Wind	Character of damage not reported	Do.
Benton, Bremen, Johnson, Monroe, Plymouth, Winneshiek, and Woodbury Counties, Iowa.	6	do			41,000	Wind and hail	do	Do.
Falls City, Hobson, and Kaines City, Tex.	6	do			77,500	Hail	Damage chiefly to crops	Do.
Mangum and Lawton (near), Okla.	6	do				do	Considerable damage to windows and roofs; minor crop damage.	Do.
Clifton, Tex.	6					Wind	Several buildings wrecked; crops injured	Do.
Coleman, Tex.	6					do	Crops damaged; oil derricks blown down	Do.
Clinton County, Iowa	7	5 a. m.			2,000	do	Character of damage not reported	Do.
Delaware County, Iowa	7	3:30 p. m.			1,500	Wind and hail	do	Do.

[1] Includes damage at Fillmore, Mo.

Severe local storms, May, 1930—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Chase to Lyons, Kans	7	5 p. m	2-3 mi.			Hail	Heavy damage to growing crops, chiefly wheat, over path 12 miles long.	Official, U. S. Weather Bureau.
Graham County, Kans	7	6-7 p. m	2-4 mi.			do	Orchards and gardens severely injured	Do.
Nekoma to Bison, Kans	7	P. m	3 mi.			do	Wheat damaged 25 to 50 per cent over path 18 miles long.	Do.
New Tazewell, Tenn	7					Wind	Buildings and trees suffer considerable damage	Do.
Anna and Cobden, Ill., and vicinity.	8	12:10 p. m	3 mi.		$10,000	Hail	Fruit and truck damaged over path 15 miles long	Do.
Wayne County, Iowa	8	5:30 p. m			200	Tornado	Character of damage not reported; path 4 miles long.	Do.
Mulberry, Ark	8	6 p. m				do	No damage reported	Do.
Furnas County, Nebr	8	6-7:30 p.m	440		50,000	Tornado and hail	Many farm buildings wrecked or damaged; trees uprooted; path 36 miles long.	Do.
Campbell, Nebr	8	5 p. m	20		2,500	Tornado	Number of houses damaged; path short	Do.
Kearney County, Nebr	8	8-8:30 p.m	25 mi.		50,000	Wind	Many farms badly damaged; wind tornadic in places; path 25 miles long.	Do.
Hastings Nebr	8	9-9:30 p.m	1,760	1	750,000	Heavy hail and tornadic winds.	Many buildings completely demolished, others damaged; telephone and light wires and trees blown down; 20 persons injured; path 4 miles.	Do.
Adams and Clay Counties Nebr.	8	9-11 p. m	15 mi.		10,000	Hail	Damage chiefly to crops	Do.
Murphy, Nebr	8	11:30 p. m	6 mi.		30,000	do	Windows broken; crops, roofs and siding damaged.	Do.
Chandler, Newbury, and vicinity, Ind.	8				7,000	do	Vegetation almost completely ruined; practically every home in Chandler damaged.	Do.
Woodbury County, Iowa	9	1:30-2:30 a. m.			1,200	Wind	No details reported	Do.
Buena Vista County, Iowa	9	2:30-2:40 a. m.			15,000	Tornado and hail	No details reported; path 8 miles long	Do.
Wright County, Iowa	9	4 a. m			1,000	Tornado	No details reported; path one-third mile long	Do.
Roff, Okla., and vicinity	9	3:30 p. m	4 mi.		30,000	Hail	Damage chiefly to crops	Do.
North Bend, Nebr	9	5 p. m	33		4,000	Tornado	Farm buildings damaged; path 10 miles	Do.
Crowder to Kinta (near), Okla.	9	5:10 p. m				do	No details reported	Do.
Lyon, Sioux, and Plymouth Counties, Iowa.	9	6 p. m			11,050	Wind and hail	do	Do.
Fillmore and Clay Counties, Nebr.	9	6:45 p. m			3,500	Wind	Trees and small buildings damaged	Do.
Polk County, Nebr	9	7 p. m	440		7,500	do	Buildings damaged; 3 persons injured	Do.
Crane, Tex., and vicinity	9	11 p. m	15 mi.		5,000	Wind and hail	Some crop loss; a few buildings unroofed; small buildings overturned.	Do.
Yarrellton to Burlington, Tex.	9		3 mi.			Hail	Cotton crop a total loss	Do.
Lakin, Kans., and vicinity	10	1 a. m	6 mi.		4,000	do	No details reported	Do.
Peck, Kans	10	8 a. m	100		100	Tornadic wind	Minor damage to property over path one-half mile long.	Do.
Booneville, Ark	10	11:30 a. m			1,000	Wind	Some damage to property	Do.
Lancaster County, Nebr. (southwestern.)	10	1:30 p. m	880		5,000	do	A number of small buildings damaged; path 7 miles long.	Do.
Crawford County, Iowa	10	3:30 p. m			5,000	do	No details reported	Do.
Haskell, Grant, Stanton, and Stevens Counties, Kans.	10	2:30 p. m				Several small tornadoes.	Farm property damaged	Do.
Clark County, Wis	10				8,000	Severe squall	Damage to farms over path 10 miles long	Do.
Ford and Clark Counties, Kans.	12	4-5 p. m			8,000	Hail	Heavy property damage near Bucklin	Do.
Tahoka, Tex	12	5 p. m	7 mi.		50,000	do	Severe damage to buildings; minor crop injury	Do.
Hondo, Tex	12	7 p. m	3 mi.		10,000	do	Crops damaged	Do.
Weatherford, Tex., and vicinity.	12	do	21 mi.		500,000	Rain, hail, and freshets.	Four-fifths of damage caused by floods; livestock killed or drowned.	Do.
Aledo, Tex	12	10 p. m	400		14,000	Wind	Damage chiefly to crops; 2 persons injured	Do.
Major, Woods, Alfalfa, Kiowa, Custer, Grant and Washita Counties, Okla.	12				450,000	Hail	Crops in much of area total loss; other property damaged.	Do.
Clinton, County, Mich	13	2:30-3 p.m	880		200,000	Tornado and hail	32 barns wrecked; many residences damaged; valuable timber ruined; orchards uprooted; path 35 miles long.	Do.
Haskell, Tex	13	3 p. m	2 mi.			Hail	Considerable damage to gardens, fruits, window, and roofs.	Do.
Rotan, Tex	13	8 p. m	6 mi.		25,000	do	Farm property damaged; all crops must be replanted.	Do.
Blaine and Lycan, Colo	14	Midnight-2 a. m.				do	Loss of crops in three-fourths of area	Do.
Johnson County, Kans	14	2 a. m	4 mi.			do	Hundreds of acres of wheat destroyed	Do.
Texas County, Okla	14	3 a. m	4 mi.		275,000	Hail	Heavy crop damage over path 20 miles long	Do.
Vernon, Tex., and vicinity	14	10:30 a. m				Wind, hail, and rain.	Crops, homes, and other property damaged	Do.
Killeen, Tex	14	4:30 p. m	2 mi.		5,000	Wind	Crops damaged	Do.
Swertner to Granger, Tex	14	6 p. m	5 mi.		10,000	Hail	Damage chiefly to crops	Do.
Lakin, Kans., and vicinity	14	7:30 p. m	3 mi.		15,000	do	Roofs and windows pierced; crops badly damaged in some areas.	Do.
Clacks, Miss. (near)	14					do	800 acres of cotton destroyed	Do.
Electra, Tex	14		6 mi.		100,000	Hail, rain and wind.	Extensive crop damage, some loss of livestock	Do.
Liberal, Kans. (15 miles west of).	14		5 mi.		20,000	Hail	Many acres of wheat beaten	Do.
Lowndes County, Ga	14					do	Corn, cotton and trees stripped	Do.
Sabinal, Tex. (near)	14		5 mi.		150,000	Wind, rain and hail.	Heavy damage to crops and other property	Do.
Garden City, Leoti, and Lakin, Kans.	15	4 a. m			20,000	Hail	Grains damaged 25 to 50 per cent in places	Do.
Custer County, Okla	15	8 a. m	5 mi.			do	Heavy crop and property damage	Do.
West Carroll and East Carroll Parishes, La.	15	2:30 p. m	3 mi.		59,000	do	Crops, roofs, windows, and auto tops damaged; path 15 miles.	Do.
Bloom, Colo	15	5 p. m	1,760			do	Sheep and small animals killed; cattle and horses severely injured; roofs and windows pierced.	Do.
Dundee to Mankins, Tex	15	5:30 p. m	440		25,000	Tornado	Buildings and derricks damaged; 6 persons injured.	Do.
Ellis, Dewey, Canadian, and Bryan Counties, Okla.	15					Hail	Many thousands of dollars damage to crops and other property.	Do.

Severe local storms, May, 1930—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Fremont Experiment Station, Colo.	15					Hail	Storm very severe; character of damage not reported.	Official, U. S. Weather Bureau.
Pittsburg, Tex.	15					Tornado and rain.	Considerable damage to crops and property	Do.
New Orleans, La.	16	3:15 p. m.	1.5 mi.		$50,000	Thundersquall	Several buildings damaged; telephone wires blown down; path 1.5 miles long.	Do.
Avondale, Colo., and vicinity.	16	3:30-4 p. m.	2-3 mi.			Hail	Considerable damage to crops and roofs of buildings.	Do.
Lufkin, Tex.	16	5 p. m.	7 mi.			do.	Tomato and other crops damaged; windows and roofs pierced.	Do.
Woodward County, Okla.	17	6 a. m.	6 mi.			do.	Crops severely damaged over path 15 miles long.	Do
Slayden, Tex.	17	10:30 a. m.	16		500	Tornado	Slight damage	Do.
Rocky Ford, Colo.	17	12:30 p. m.	3 mi.		40,000	Hail	Severe damage to crops and small fruits; some poultry killed.	Do.
Lamar, Colo., and vicinity.	17	1 p. m.	10-15 mi.		50,000	do.	Crops damaged and livestock killed	Do.
Mont Belview, Tex.	17	3 p. m.	100		6,000	Tornado and rain.	Derricks damaged; 6 persons injured	Do.
Bristol, Colo. (near)	17	5 p. m.	6 mi.		25,000	Hail	Crops damaged	Do.
Dublin, Tex. (near)	17	6 p. m.	6 mi.			Hail and wind	Severe losses to crops; poultry killed; roofs damaged.	Do.
Cleburne, Tex.	17	7 p. m.	6 mi.		500,000	do.	Extensive property damage	Do.
Ballinger, Tex.	17	8:30 p. m.				Hail	Livestock and poultry killed; all crops considerably damaged.	Do.
Ellis to Dallas Counties, Tex.	17	do.	3 mi.	3		Rain, hail, and wind.	Widespread damage to crops and other property.	Do.
Madison, Tex.	17	9 p. m.	50		3,500	Tornado	Chief damage to property other than crops	Do.
Breckenridge, Tex.	17					do.	Several oil derricks demolished	Do.
Broken Arrow, Okla. (near)	17					do.	Minor property damage	Do.
Marion, Ark.	18	10:30 a. m.	440	4	7,500	do.	Some property destroyed or damaged; 8 persons injured.	Do.
Somerville, Tenn. (near)	18	Noon	200		25,000	do.	Business property damaged; many shade trees broken; 4 persons injured.	Do.
Tichnor to Wabash, Ark.	18	3:30 p. m.		14	14,500	do.	34 persons injured; considerable property damage.	Do.
Chattanooga, Tenn.	18	P. m.				Thunderstorm and wind.	Falling trees and limbs broke telephone and electric wires; cars delayed; streets flooded and badly washed.	Do.
Knoxville, Tenn.	18					do.	Trees and poles blown down paralyzing traffic; minor damage to buildings.	Do.
Taylor County, Tex.	18					Hail	Crops severely damaged	Do.
Startup, Wash.	20	2:30 p. m.	1,700			Hail and wind	Fruits considerably damaged	Do.
Black Hawk County, Iowa.	20	5-6 p. m.			55,200	Hail, wind and flood.	Heavy damage by hail; considerable damage by flood.	Do.
Wewahitchka, Fla. (15 miles north of).	22	12:30 p. m.				Hail	Considerable damage to crops	Do.
Tallahassee, Fla. (6 miles east of).	22	4:30-5 p. m.	880			do.	Corn, cotton, and cane damaged; poultry killed	Do.
Clare to West Branch, Mich.	23	1:30-3 p. m.	880-1,760		200,000	Tornado followed by hail.	Property of all kinds severely damaged or destroyed.	Do.
Madison, Fla. (6 miles south of).	23	5 p. m.			1,000	Hail	Tobacco, cotton, and corn damaged	Do.
Baltimore, Md.	24			4		Thunderstorm and squall.	Storage plant unroofed; some damage by flooding.	Do.
Streator, Ill., and vicinity.	27	5:30-5:40 p. m.	880-3,520		140,000	Tornado	Heavy property damage; livestock killed; 8 persons injured; path 15 miles long.	Do.
Fort Assiniboine, Mont. (near).	28					Wind	Many acres of crops ruined, necessitating reseeding.	Do.
Kalispell, Mont.	29	5:12 p. m.			1,500	Hail	Vegetable and flower gardens injured; glass in greenhouses and residences broken.	Do.
Arriba, Colo.	31	4-5 p. m.			5,000	Wind	Grain badly whipped	Do.
Wagon Mound, Mora County, N. Mex.	31	5 p. m.	300	2	150,000	Tornado	40 dwellings and 8 business houses more or less wrecked; 20 persons injured.	Do.

RIVERS AND FLOODS

By R. E. SPENCER

The most severe floods of May were those in the Shreveport, La., river district along the Red and Sulphur and Cypress Rivers. Others of some importance, resulting from the same general rains, occurred to the southwestward in the rivers of east and central Texas, to the northward in the Arkansas and White Rivers, and to the eastward in the Ouachita and Pearl Rivers.

The rains which caused these rises, while most concentrated in northeastern Texas, were fairly continuous and occasionally excessive between May 3 and 17–18 from central Texas and Oklahoma eastward to Mississippi. The heaviest falls occurred at three and four day intervals beginning with the third.

In the Shreveport district, comprising the Red River and its tributaries above Shreveport, La., the streams rose steadily following the third, beginning with comparatively low to moderate stages and reaching flood stages and crests as indicated in the table at the end of this report. The crests at Finley, Tex., on the Sulphur River, and at Jefferson, Tex., on the Cypress River, were the highest of record. Warnings were first issued for the Sulphur River, on the 3d, and with continued rains were subsequently amplified as necessary to cover the entire district. These forecasts were timely and adequate, and their dissemination was accomplished in a very effective manner, with the result that only five lives were lost, and about $990,000 worth of livestock and other movable property were saved.

Concerning losses and the extent of overflow, the official in charge of the Weather Bureau office at Shreveport reports as follows:

The total loss in the Shreveport river district has been estimated at $2,370,000. This figure covers the sections in Texas overflowed by the Sulphur and Cypress Rivers and the area overflowed by the Red River and its tributary bayous and creeks from the vicinity of New Boston, Tex., and Idabel, Okla., to the vicinity of Ninock, La., the river distances along the Red being about 300 miles. In Arkansas and Louisiana most of the damage resulted from the overflow of bayous and creeks back of the levees, and in Caddo Parish, La., the overflow was augmented to a great extent by the record-breaking flood waters from the Cypress River, which has an outlet into Caddo Lake and thence by connecting bayous and drainage canals to Cross Bayou that empties into Red River within the northern city limits of Shreveport. Cross Bayou is also an outlet for Cross Lake. Cross Lake is dammed to form a reservoir of many square miles for the main water supply of Shreveport.

Specifically, the flood losses along the respective rivers were as follows:

	Sulphur River	Cypress River	Red River at and above Shreveport, La.	Total
Tangible property (bridges, buildings, highways, etc.)	$115,500	$100,000	$525,500	$741,000
Matured crops	36,000		24,000	60,000
Prospective crops	162,000	25,000	1,225,000	1,412,000
Livestock and other movable farm property	6,500	1,000	3,500	11,000
Suspension of business	26,000	5,000	115,000	146,000
Total	346,000	131,000	1,893,000	2,370,000
Value of property saved by warnings	87,000	15,000	888,000	990,000

Estimates of the acreage covered by flood waters to a considerable depth were: Along Sulphur River, about 23,500 acres; along Cypress River, 15,000 acres; along Red River, 151,500 acres; total, 190,000 acres.

Losses, especially heavy in prospective crops, included also damage to a considerable number of oil wells and the loss of hay and spring vegetables, as potatoes, tomatoes, etc. Loss of movable property included very little live stock.

Damage to levees, fronting Red River, in the vicinity of Shreveport amounted to about $100,000 in addition to the above.

In the Houston, Tex., district, which comprises the Sabine, Neches, and Brazos Rivers, and the Trinity River from Long Lake, Tex., to the mouth, the floods were comparatively less severe and the destruction proportionally less. A brief statement of the overflow in the neighborhood of Weather Bureau gaging stations is given by the official in charge of the Weather Bureau Office at Houston:

The Trinity overflowed its banks at Long Lake for one-half to 1 mile on the right and 1 to 2 miles on the left bank; at Riverside, one-fourth mile on the right and 1½ miles on the left bank; at Liberty about 5 miles on the right bank. The Sabine at Logansport, La., overflowed both banks about 2½ miles.

Stage forecasts were accurate and a saving of $198,200 was effected through their use. A tentative estimate of losses places the total at $895,350, distributed as follows:

	Brazos and tributaries	Trinity	Sabine
Tangible property	$71,000	$50,500	
Matured crops	[1] 1,600	[2] 50,000	2,000 acres.
Prospective crops (mostly cotton)	[3] 244,000	[4] 105,500	1,000 acres.
Livestock and other movable property	10,500	12,500	$1,000.
Suspension of business	31,500	61,500	$5,750.
Additional, in Anderson County		250,000	
Savings by flood warnings	40,500	132,500	$25,200.

[1] 8 acres. [2] 3,000 acres. [3] 14,050 acres. [4] 8,000 acres.

Along the Trinity River (including Elm Fork) above Long Lake., Tex., three persons were drowned and losses totaled at least $95,290, distributed as follows:

To highways	$3,200
Resulting from levee breaks below Dallas, Tex	2,000
Levee damage in the Dallas Levee District	2,000
Prospective crops (6,000 acres)	9,000
Movable property	7,000
Suspension of business	72,090

The value of property saved through the use of Weather Bureau flood warnings was about $122,000.

The only important damage done by the Arkansas and White rises was that to prospective crops, several thousand acres of planted low lands having been inundated. As the season is not too far advanced, however, this area can be replanted.

Of the floods in the Ouachita and lower Red Rivers Mr. R. A. Dyke, of the Weather Bureau Office at New Orleans, La., reports in part as follows:

Rainfall was especially heavy in the Ouachita Basin on May 16–19, with 8.55 inches at Arkadelphia and 12.45 inches at Camden; 7.50 inches occurred at Prescott, Ark., on the Little Missouri; and an average of 7 to 8 inches fell over the basin below Camden. The excessive rainfall over the Smackover and Eldorado oil sections caused a large overflow of Smackover Creek on the 18th-19th, with much damage to oil stores, wells, and equipment in those sections before the main crest of the flood in the Ouachita channel arrived there.

Reports of losses resulting from this flood are incomplete. In Nevada County, Ark., drained largely by the Little Missouri River, crop losses were estimated at 20 per cent, and damage to bridges amounted to about $10,000. From Camden, Ark., it is reported that in Ouachita, Dallas, Union, Calhoun, Bradley, and Columbia Counties roads were damaged to the extent of $70,000, and prospective crop losses of $20,000 occurred; loss due to suspension of business was $2,000; money value of property saved by warnings was about $10,000. From Felsenthal, in extreme southeastern Union County, a loss of $250 to prospective crops and of $200 worth of livestock is reported. There were some losses from flooding of oil wells near the Arkansas-Louisiana line. It has been impracticable to obtain estimates of the losses in the oil fields, which newspaper reports give indefinitely as "several million dollars." In addition, many people were rendered homeless in the Smackover area.

The warnings enabled stockmen to remove cattle from the bottoms to places of safety.

The flood in the Red River below Shreveport, La., was due chiefly to the rainfall of May 16–19, occurring at a time when the river was rising because of previous rains. Heavy rains of 8 inches or more, over the area draining into Red River through Lake Bisteneau, contributed materially to the rise, causing a higher stage at Alexandria than would have been expected from the crest stage at Shreveport, and the carrying capacity of the channel below Shreveport as indicated by stages in the first part of the rise. Rainfall from other parts of the basin draining into the Red River below Shereveport and above Alexandria was not remarkably heavy; the amounts ranged from 1.65 inches at Grand Cane, La., to 5.75 inches at Arcadia, La.

A report of losses along this reach of the Red River will appear in a later issue of the REVIEW.

Damage done by the floods in the Pearl system was comparatively slight:

Bridges, highways, lumber, etc	$7,700
Prospective crops (3,000 acres)	18,500
Livestock and other movable property	100
Suspension of business	22,500
Total	48,800

In addition to a saving of about $5,000 in movable property, the flood warnings were especially valuable in preventing livestock losses.

As a result of the Tombigbee-Black Warrior flood a considerable area of the lowest bottom lands of the Black Warrior from above Tuscaloosa to the mouth of the river, a distance of about 150 miles, was flooded, and lowlands of the Tombigbee at places above Demopolis and more extensively below that point, for a distance of about 180 miles, and extending inland as much as 2 miles, were also inundated.

Reports of damage, undoubtedly incomplete, give the following figures:

Tangible property (mostly highways)	$14,400
Matured crops	2,000
Prospective crops (40,000 acres)	220,000
Livestock and other movable property	7,900
Suspension of business	29,500
Total	273,800
Value of property saved through Weather Bureau flood warnings	112,000

The Verdigris River flood, arising from heavy local rains in northeastern Oklahoma and southeastern Kansas,

on April 29 and 30, overflowed approximately 6,000 acres and damaged crops to the extent of about $100,000 and tangible property to about $25,000. The greater part of the damage occurred in Montgomery County, Kans. Eight thousand dollars was saved through the Weather Bureau flood warnings.

Damage amounting to about $10,500 resulted from the Kansas and Big Blue River floods—$6,000 in railroad and bridge damage near Belvue, Kans., and $4,500 in the vicinity of Beatrice, Nebr. The value of warnings issued for these rises was about $3,500.

The remaining May floods were, in the main, unimportant. That in the Illinois River, continuing from April, caused no loss and little inconvenience. On the lower Rio Grande slight damage was done to a road under construction near Brownsville, Tex. The Pacific drainage rises were without material consequence.

A belated report of damages resulting from the Tallahatchie River flood of January-April places the loss in crops at $3,000. The flood beginning on May 18 in this stream will be discussed later.

[All dates in May unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
EAST GULF DRAINAGE	*Feet*			*Feet*	
Tombigbee: Lock No. 4, Demopolis, Ala.	39	20	[1]	54.3	28
Black Warrior: Lock No. 10, Tuscaloosa, Ala.	46	19	22	56.5	20
Pearl:					
Edinburg, Miss.	21	19	25	24.9	22
Jackson, Miss.	20	20	[1]	31.9	28
Monticello, Miss.	18	20	23	20.8	20
Columbia, Miss.	18	20	25	21.2	23
West Pearl: Pearl River, La.	13	23	[1]	15.4	24
MISSISSIPPI DRAINAGE					
Illinois:					
Peru, Ill.	14	[2]	14	18.8	Apr. 23
Henry, Ill.	10	[2]	9	13.3	Apr. 25
Peoria, Ill.	18	[2]	4	19.9	Apr. 26
Havana, Ill.	14	[2]	14	16.2	Apr. 28-29
Beardstown, Ill.	14	[2]	14	16.8	Apr. 30
Pearl, Ill.	12	[2]	8	12.7	1-4
Kansas:					
Wamego, Kans.	16	8	8	16.0	8
Topeka, Kans.	21	8	8	22.0	8
Lawrence, Kans.	18	8	8	18.5	8
Smoky Hill: Lindsborg, Kans.	19	7	8	21.5	7
Big Blue:					
Beatrice, Nebr.	16	14	15	17.7	14
Randolph, Kans.	21	8	8	22.7	8
Arkansas:					
Dardanelle, Ark.	20	11	17	24.3	11
Morrilton, Ark.	20	11	12	22.0	12
Yancopin, Ark.	29	13	27	31.5	23
Verdigris:					
Independence, Kans.	30	[2]	1	38.4	1
		8	8	30.4	8
Sageeyah, Okla.	35	2	3	35.3	2
North Canadian: Woodward, Okla.	4	16	16	4.0	16
Petit Jean: Danville, Ark.	20	10	14	25.3	12
White:					
Calico Rock, Ark.	18	11	11	21.3	11
Batesville, Ark.	23	11	12	28.7	12
Georgetown, Ark.	22	14	22	23.2	19
De Valls Bluff, Ark.	24	19	23	24.4	20
Black: Black Rock, Ark.	14	11	12	16.1	12
Cache: Patterson, Ark.	9	20	20	9.0	20
Tallahatchie: Swan Lake, Miss.	25	18	[1]	30.3	29-30
Red:					
Index, Ark.	27	20	21	27.2	21
Fulton, Ark.	28	17	27	32.5	22
Springbank, Ark.	37	23	26	37.7	24
Alexandria, La.	36	25	[1]	41.2	June 5-6
Sulphur:					
Ringo Crossing, Tex.	20	4	24	27.2	17
Finley, Tex.	24	12	28	31.7	19
Cypress: Jefferson, Tex.	18	17	27	28.6	20
Lake Bisteneau: Ninock, La.	28	22	-------	34.6	27
Ouachita:					
Arkadelphia, Ark.	12	11	13	19.2	12
		18	20	19.6	19
Camden, Ark.	30	13	27	40.7	21

[1] Continued at end of month. [2] Continued from last month.

[All dates in May unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
WEST GULF DRAINAGE	*Feet*			*Feet*	
Sabine: Logansport, La.	25	24	[1]	34.1	28-29
Trinity:					
Dallas, Tex.	25	12	26	36.3	14
Trinidad, Tex.	28	8	[1]	42.7	21
Long Lake, Tex.	40	13	[1]	46.7	23
Riverside, Tex.	40	25	[1]	45.8	29
Liberty, Tex.	25	18	[1]	27.9	June 3
Trinity, Elm Fork: Carrollton, Tex.	7	14	14	7.1	14
Brazos:					
Waco, Tex.	27	18	19	29.3	18
Washington, Tex.	45	21	22	45.9	21
Rio Grande:					
San Marcial, N. Mex.	3	[2]	3	3.8	April 28
		6	6	3.1	6
San Benito, Tex.	23	31	[1]	23.5	June 2
PACIFIC DRAINAGE					
Colorado: Parker, Ariz.	7	[2]	[1]	9.1	1, 2, 4, 5, 9, 10, 11.
Colorado, Roaring Fork:					
Carbondale, Colo.	5	31	31	5.1	31
Gunnison: Delta, Colo.	9	29	31	9.3	31

[1] Continued at end of month. [2] Continued from last month.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MAY, 1930

By J. B. KINCER

General summary.—During the first decade showers and some beneficial rains occurred in the Southwest and parts of the South and Southeast, but in most Eastern States little or no relief from the drought was afforded. In these droughty areas spring planting was retarded and germination and growth were slow, but in the heretofore dry Southwest many areas were too wet, with farm work retarded and some injury from washing soil. Outside of these areas the weather was largely favorable with the crop season 10 days to two weeks ahead of the average, although it was somewhat too cool for best growth in the West.

During the second decade unseasonably low temperatures in the interior valleys retarded growth of warm-weather crops, with more or less local frost injury reported over a considerable area in the central-northern portion of the country. Frequent rains and wet soil delayed farm work in most trans-Mississippi sections, while there was some damage by washing soil and flooding lowlands in the lower Mississippi Valley and sections to the westward; otherwise farm work made generally good progress.

During the last decade temperatures continued too low for good growth and this coolness, together with deficient rainfall, retarded progress of practically all crops, and especially those of the warm-weather variety. Heavy to killing frosts were reported from the northern tier of States from the Lake region westward, but damage was confined chiefly to gardens and truck. Less rainfall in the south-central portion of the country, especially in the lower Mississippi Valley, was favorable, but rain was generally needed in most parts from the Ohio Valley eastward and locally elsewhere.

Small grains.—During the first decade continued dry weather in most parts of the eastern Winter Wheat Belt resulted in rather poor advance of the crop, although there was some temporary relief by showers locally. In Kansas rainfall varied widely, but wheat showed improvement, with heading noted in south-central and southeastern parts. Rains improved conditions in the more south-

western belt and local showers were helpful in the South and East. Spring wheat was growing nicely and oats showed some improvement; other small grains made satisfactory advance.

During the second decade cool weather delayed advance of winter wheat in many sections, but in Kansas growth was satisfactory, except for some locally wet areas, while in the Southwest progress was good. In the Ohio Valley growth ranged from slow to fair, but many fields were spotted and thin. Spring wheat was also delayed by coolness, but the crop was well stooled; oats made slow advance, while other small grains did well.

During the last decade winter wheat made fair advance in the Ohio Valley, but condition ranged widely, from poor to very good, and the crop was heading generally on short straw. Conditions were favorable in Kansas, with wheat practically all headed in the south-central and southeast. Harvest was under way in Texas and the crop was ripening in southern Oklahoma. Spring wheat was favored, while oats ranged from poor to good; other small grains continued to make satisfactory advance.

Corn.—During the first decade frequent rains and wet soil retarded corn planting in the Great Plains and the upper Mississippi Valley, although in Iowa seeding was fairly abreast of the season, with about the normal amount planted and some cultivation done. In Missouri, Illinois, and Indiana the weather was generally favorable, but from the upper Ohio Valley eastward the soil was too dry for germination. During the second decade the weather was mostly unfavorable for germination and growth of corn, with much cool, wet weather, although showers improved condition of the soil in the Ohio Valley. Planting made fair to very good advance in Iowa, but germination was slow and cultivation needed, with color mostly poor. During the last decade the weather was favorable for field work in the principal corn-producing sections and late planting advanced well. Some corn was up as far north as southern Michigan and southern North Dakota, while farther south considerable cultivation was accomplished. The situation in the central Corn Belt was better than last year, when planting had barely begun because of continued wetness.

Cotton.—During the first decade rain was still needed in the eastern Cotton Belt, but showers were helpful in central sections; there was too much moisture in western parts. In Texas progress of cotton was mostly good in the outhern third, but rather poor elsewhere due to heavy rains, washing soil, and local storms, with planting and chopping delayed in the north. In Oklahoma planting was retarded by heavy rains, while in the Mississippi Valley States and northern east Gulf area the weather was favorable. In the eastern belt germination and growth were slow with stands irregular and a general rain needed.

During the second decade conditions were favorable east of the Mississippi Valley, but unfavorable to the westward. In Texas progress of cotton was mostly good in the south third of the State, but elsewhere rains and wet soil were unfavorable, with cultivation and chopping mostly at a standstill in the northern two-thirds. In Oklahoma, Arkansas, northern Louisiana, Mississippi, and extreme western Tennessee there was too much rain, with much cotton washed out and many lowlands flooded. To the eastward of this area showers were very beneficial and progress of the crop was mostly fair to good.

During the last decade night temperatures were too low for good growth, but rainfall was light over the central areas where it had been wet previously, which made conditions more favorable. In Texas progress of cotton was good in the south third, though the nights were too cool; elsewhere it was rather poor, while in large areas the soil was too wet to work and fields were becoming grassy. In Oklahoma conditions were mostly favorable and advance was generally very good and planting advanced rapidly in the west and north. In central portions the weather favored drying out the soil and some cultivation was accomplished, but in general, the soil was too wet, hindering working. In eastern areas showers were helpful, but parts were still too dry. Chopping was becoming more active, but field work was hindered by rains locally.

Miscellaneous crops.—Pastures and meadows were unfavorably affected by the dry weather in the eastern and southeastern sections of the country, but elsewhere conditions were mostly satisfactory, especially in the great western grazing area. Livestock were favored generally, although there was some delay to shearing locally; lambing was still progressing at the end of the month in limited areas.

Except for some slight frost injury to tender truck and potatoes in the more northern States, these crops did well throughout the month, although rain was needed in some parts. Sugar beet thinning advanced in western States, while sugarcane was benefited by showers in Louisiana. Tobacco transplanting made only slow progress in Kentucky, but plants were healthy, although small, in Wisconsin. Fruits continued satisfactory advance, with late reports on the effect of the April freeze in the important commercial apple sections of the Virginias indicating that damage was spotted and, in general, less than at first feared.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

Taking the ocean as a whole, there was a marked decrease in the severity of the weather during May as compared with the previous month. The gales were comparatively evenly distributed over the different sections, but were not reported on more than 3 days in any 5° square, and in few instances was the wind force as high as 10. The total number of storm reports received was also considerably less than usual.

The most unusual feature was the disturbance that first appeared in the western part of the Gulf of Mexico on the 29th, that will be referred to later.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, May, 1930*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Belle Isle, Newfoundland	29.88	[1] −0.06	30.46	25th	29.30	13th.
Halifax, Nova Scotia	29.92	[2] −0.05	30.34	12th	29.46	4th.
Nantucket	29.96	[2] −0.03	30.38	12th	29.72	4th.[3]
Hatteras	30.07	[2] +0.04	30.26	12th	29.70	15th.[3]
Key West	30.01	[2] +0.03	30.16	20th	29.78	30th.
New Orleans	30.04	[2] +0.04	30.26	20th	29.80	30th.
Cape Gracias, Nicaragua	29.90	[1] 0.00	29.98	13th [3]	29.84	30th.
Turks Island	30.08	[1] +0.08	30.22	19th [3]	30.00	1st.
Bermuda	30.12	[2] +0.01	30.32	17th [3]	29.90	4th.[3]
Horta, Azores	30.14	[1] +0.13	30.46	24th [3]	29.86	21st.
Lerwick, Shetland Islands	29.90	[1] +0.10	30.35	23d	29.14	18th.
Valencia, Ireland	29.99	[1] +0.04	30.28	20th [3]	29.58	10th.
London	29.97	[1] +0.05	30.23	19th	29.49	11th.

[1] From normals shown on Hydrographic Office pilot charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date or dates.

As is usually the case during a month of moderate weather, fog was very prevalent over a large section of the ocean. The number of days on which it was reported in different localities is as follows: Along the American coast between the thirty-fifth and fiftieth parallels, from 6 to 11 days; over the Grand Banks, from 14 to 20 days; over the middle section of the steamer lanes, from 3 to 7 days; along the European coast, from 2 to 4 days; in the Straits of Gibraltar, 4 days.

Charts VIII to XI cover the period from the 1st to 4th inclusive, and show the disturbance over the middle and eastern sections of the steamer lanes.

During the first 12 days of the month the North Atlantic HIGH was unusually well developed, reaching its maximum on the 11th, with a barometric reading of 30.42 inches at Horta. From the 5th to 10th the Maritime Provinces were covered by an area of low pressure, and on the 8th moderate southerly gales were reported by vessels between the fortieth and fiftieth parallels and the thirty-fifth and forty-fifth meridians.

From the 11th to 19th low pressure was general off the coast of northern Europe, and on the 11th westerly gales occurred in the southerly quadrants, while on the 18th a well-developed disturbance of limited extent was central near Lerwick, with moderate to strong westerly to northwesterly gales over the area between the British coast and fifteenth meridian.

On the 20th a moderate depression was central near 40° N., 43° W., and from the 21st to 24th very much the same conditions existed along the fortieth parallel, between the fiftieth and sixtieth meridians.

From the 25th to 29th moderate weather prevailed over the ocean generally, although on the 29th there was a LOW over the western section of the steamer lanes, and on that date a LOW was also central near Brownsville, Tex., that afterwards developed into a well-defined disturbance as it moved eastward, although of limited intensity and extent. On the 30th the center was near Tampa where the barometer read 29.66 inches; thence it moved rapidly northeastward, decreasing in intensity, and on the 31st was in the vicinity of Nantucket.

OCEAN GALES AND STORMS, MAY, 1930

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Ala, Am. S. S.	Antwerp	New York	48 45 N	31 32 W	Apr. 30	4 a, May 1	May 2	29.42	SSE	W, —	W	WSW, 10	SW-W.
Hellig Olav, Dan. S. S.	Oslo	Halifax	54 25 N	26 21 W	May 3	6 a, 4	May 4	28.95	ESE	NW, 9	NW	NW, 9	SE-S-W-NW.
American Shipper, Am. S. S.	London	New York	44 40 N	39 00 W	May 8	4 a, 8	May 8	29.82	SW	S, 9	SW	S, 9	S-SW.
Cottico, Du. S. S.	Amsterdam	do	49 15 N	3 30 W	May 11	4 a, 11	May 11	29.65	WSW	SSW, —	W	W, 8	SW-W.
Wytheville, Am. S. S.	Antwerp	do	47 30 N	34 44 W	May 11	1 a, 12	May 14	29.43	SW	W, 4	WNW	SW, 9	SW-W-NW.
Cyrus Field, Br. S. S.	Halifax	Cable repairs	47 40 N	53 47 W	May 12	6 a, 13	May 13	29.36	WSW	SW, 7	SW	SW, 9	
Sarcoxie, Am. S. S.	New York	Havre	47 05 N	37 17 W	May 13	4 a, 14	May 14	29.85	SW	WSW, —	WSW	WSW, 8	Steady.
Jean Jadot, Belg. S. S.	Antwerp	New York	49 00 N	24 40 W	May 14	3 p, 14	May 14	29.73	WSW	WSW, 8	W	WSW, 8	
Mount Evans, Am. S. S.	New Orleans	London	39 28 N	63 50 W	May 15	7 p, 15	May 16	29.96	S	S, 7	SW	SW, 8	S-SW.
Exporter, Am. S. S.	Lisbon	New York	40 48 N	28 30 W	May 17	9 p, 17	May 17	29.77	N	N, 10	NE	—, 10	SW-W-N.
Quaker City, Am. S. S.	Dundee	Philadelphia	58 35 N	2 29 W	May 18	3 a, 18	May 19	29.24	SW	SW, 8	W	W, 9	
Iowan, Am. S. S.	Canal Zone	New York	14 25 N	5 18 W	May 18	Noon, 18	May 18	29.98	NE	ENE, 8	ENE	ENE, 8	NE-ENE.
Pres. Van Buren, Am. S. S.	Marseille	do	41 17 N	33 43 W	May 20	11 p, 20	May 21	29.61	SW	SW, —	WNW	SW, 10	SW-W.
City of Alton, Am. S. S.	Rotterdam	do	41 31 N	60 15 W	May 21	Noon, 21	May 22	29.72	W	W, 7	NW	NW, 8	W-WNW.
Excellency, Am. S. S.	New York	Casa Blanca	39 50 N	48 37 W	May 24	Noon, 24	May 25	29.80	SE	SE, 8	SW	SE, 8	SE-S.
Europa, Ger. S. S.	English Channel.	New York	41 42 N	50 17 W	May 26	7 p, 26	May 26	29.65	SW	WSW, —	W	WSW, 8	SW-W.
New York, Ger. S. S.	Cherbourg	do	41 48 N	57 20 W	May 29	3 p, 29	May 29	29.35	S	W, —	NW	SW, 8	S-W-NW.
Commercial Bostonian, Am. S. S.	Mobile	Boston	27 00 N	85 10 W	May 29	8 p, 29	May 30	29.62	SE	SE, —	—	—, 8	SE-S-SW.
Tuscaloosa City, Am. S. S.	Canal Zone	New York	29 00 N	79 00 W	May 30	4 p, 30	May 31	29.65	SSW	SW, 6	NNE	NNE, 8	SW-NNE.
Abercos, Am. S. S.	Galveston	Liverpool	39 00 N	63 23 W	May 30	8 p, 30	May 31	29.75	SSW	SSW, 7	SSW	SSW, 10	Steady.
Savoia, Ital. S. S.	Genoa	New York	38 29 N	60 40 W	May 31	4 p, 31	June 1	29.56	SW	SW, 10	SW	SW, 10	SW-NW.
NORTH PACIFIC OCEAN													
Silverbelle, Br. M. S.	San Francisco	Yokohama	43 11 N	176 53 W	May 1	Noon, 1	May 1	29.88	SSE	SSE, 8	WNW	SSE, 9	Steady.
Mojave, Am. S. S.	San Pedro	do	30 24 N	164 50 E	May 2	10 a.m., 2	May 3	29.92	N	SW, 5	ENE	N, 9	SW-N.
Somedono Maru, Jap. S. S.	Yokohama	Coos Bay	37 39 N	144 31 E	May 2	4 a.m, 3	May 3	29.60	SSE	S, 9	NW	WNW, 9	S-SW-WNW.

Ocean gales and storms, May, 1930—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN—continued			° ′	° ′				Inches					
Pres. McKinley, Am. S. S.	Victoria	Yokohama	52 49 N	160 35 W	May 4	8 p.m., 7	May 8		W	SSE, 2	NW	NW, 8	W-SSE-WNW-N.
Waitemata, Br. S. S.	Suva	Vancouver	44 26 N	131 48 W	May 6	4 p.m., 6	May 7	30.16	NW	NW, 9	NW	NW, 9	WNW-NNW-WNW.
Mojave, Am. S. S.	San Pedro	Yokohama	33 40 N	144 06 E	May 6	Mdt., 6	May 6	29.75	SW	SSW, 7	SSW	SW, 8	SW-SSW-SW.
Admiral Watson, Am. S. S.	Seattle	Kodiak	59 12 N	147 40 W	May 7	—, 8		29.80	E	E, 5	—	E, 8	E-SE-S-SW.
Los Alamos, Am. M. S.	San Francisco	Portland, Oreg	38 31 N	123 45 W	May 7	4 a.m., 8	May 9	29.93	NW	NNW, 7	NNW	—, 8	WNW-NW-NNW.
Havre Maru, Jap. S. S.	Kobe	San Francisco	49 30 N	172 20 E	May 8	10 a.m., 9	May 9	29.23	ESE	E, 9	SW	E, 9	
Koyo Maru, Jap. S. S.	Yokohama	Grays Harbor	44 28 N	160 15 E	May 10	8 p.m., 11	May 13	29.37	ESE	SW, 6	NE	ESE, 8	ESE-SSW-NE.
Tecumseh, Br. S. S.	do	San Pedro	44 19 N	165 48 E	May 18	6 p.m., 18	May 19	29.40	SSE	SSW, 8	W	WSW, 8	S-SSW-SW.
Shikisan Maru, Jap. M. S.	Portland, Oreg	Yokohama	49 41 N	173 19 E	May 19	4 a.m., 20	May 20	29.36	SW	WSW, 8	SW	W, 9	SW-W-S-SW.
Tecumseh, Br. S. S.	Yokohama	San Francisco	46 15 N	178 52 E	May 20	Mdt., 20	May 20	30.05	SW	SW, 8	WSW	SW, 8	Steady.
Golden Dragon, Am. S. S.	San Francisco	Shanghai	42 45 N	147 48 E	May 20	do	May 20	29.12	S	S, 8	WSW	S, 9	SSE-S.
Makiki, Am. S. S.	Hilo	San Francisco	37 09 N	124 26 W	May 21	Mdt., 21	May 22	30.15	NW	NW, 8	NW	—, 8	Steady.
Mojave, Am. S. S.	Kobe	San Pedro	46 48 N	156 35 W	May 22	4 a.m., 24	May 24	29.52	S	SSE, 7	SE	SSE, 10	Do.
Tecumseh, Br. S. S.	Yokohama	San Francisco	46 16 N	155 43 W	May 23	6 a.m., 24	May 24	29.50	SSE	S, 7	S	SSE, 9	Do.
Pres. Grant, Am. S. S.	Seattle	Yokohama	49 10 N	169 58 E	May 24	4 p.m., 25	May 26		SE	SSW, 9	W	—, 10	SE-S-W.
Wilhelmina, Am. S. S.	do	Honolulu	37 50 N	141 25 W	Mry 25	6 a.m., 26	May 27	29.70	SE	SSW, 6	NW	SSW, 8	SE-S-SW-NW.
Golden Star, Am. S. S.	Shanghai	San Francisco	49 17 N	135 57 W	May 26	9 p.m., 26	May 26	29.67	SSW	SSW, 7	SW	SSW, 10	Steady.
San Pedro Maru, Jap. M. S.	Tokuyawa	do	43 00 N	176 25 W	May 27	2 a.m., 28	May 29	29.20	E	W, 2	W	WNW, 8	NE-SW-WNW.
Grays Harbor, Am. S. S.	Tacoma	Yokohama	51 48 N	168 18 W	May 28	1 a.m., 29	May 29	28.90	E	NE, 4	NW	E, 8	E-NE.
Akagisan Maru, Jap. M. S.	Yokohama	San Francisco	47 39 N	175 32 W	May 30	6 p.m., 30	June 1	29.03	SW	SW, 7	WSW	WSW, 8	SW-WSW.

NORTH PACIFIC OCEAN

By F. G. TINGLEY

The average pressure during May throughout the region embracing the Aleutian Islands and Gulf of Alaska showed only a slight change from the preceding months of March and April. With the advance of the season pressure in the Aleutian area normally rises, the change from December to June, using the records at Dutch Harbor as a basis of comparison, amounting to 0.40 inch, the pressure values for the months named being, respectively, 29.58 and 29.98 inches. During the month under consideration pressure in this region actually fell slightly instead of rising. The average values at Dutch Harbor, St. Paul, and Kodiak were, respectively, 29.60, 29.61, and 29.77 inches as compared with corresponding April values of 29.81, 29.76, and 29.72 inches. At the same time pressures at Midway Island, Honolulu, and Juneau were slightly higher than in April, contributing further to the steepness of the barometric gradient throughout this extensive region. The pressure values of these and other island and coast stations are given in the accompanying table.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, at indicated hours, North Pacific Ocean and adjacent waters, May, 1930*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [3]	29.98		30.44	11th [6]	29.70	5th.
Dutch Harbor [2] [3]	29.60	−0.30	30.16	21st	29.02	29th.
St. Paul [3]	29.61	−0.25	30.08	21st	29.30	14th. [6]
Kodiak [3]	29.77	−0.10	30.30	11th	29.12	4th.
Midway Island [3]	30.19	+0.10	30.30	17th [6]	30.06	14th. [6]
Honolulu [4]	30.09	+0.04	30.16	3d	30.02	22d. [6]
Juneau [4]	29.96	−0.03	30.30	25th	29.58	16th. [6]
Tatoosh Island [4] [5]	30.02	−0.02	30.45	22d	29.57	20th.
San Francisco [4] [5]	29.99	+0.01	30.27	21st	29.64	4th.
San Diego [4] [5]	29.96	+0.03	30.09	9th	29.77	4th.

[1] For 26 days.
[2] For 30 days.
[3] P. m. observations only.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.
[6] And on other date or dates.

The North Pacific HIGH was fairly well developed throughout the month, and moderately high pressure extended from the coast of North America westward to midocean.

Notwithstanding the more pronounced pressure distribution just described the weather of the North Pacific during May was relatively quiet and very favorable to shipping. Few gales were experienced, chiefly of forces 8 and 9. On only three occasions during the month were winds of force 10 reported. These occurrences were on the 23d, 25th, and 26th, in widely separated regions. The amount of fog appears to have been less than usual for the season. Two tropical storms have been reported, one, a typhoon in the Philippines, described in the subjoined article by the Rev. José Coronas, S. J., chief of the meteorological division of the Philippine Weather Bureau.

The accentuation of the Aleutian LOW at this late date gave rise to considerable rain and some snow over the central portion of the northern steamship routes.

The month opened with the North Pacific HIGH well developed, having a central isobar of 30.50 inches embracing the region from 35° to 40° N. latitude, 145° to 155° W. longitude. There was a minor depression over Bering Sea. This general arrangement of pressure continued for several days, the HIGH being reinforced from the westward and the depression to the northward increasing in intensity and moving eastward over Alaska. With the passage of the latter an anticyclone advanced southeastward over the Continent and from the 7th to the 9th high pressure bridged the region between this anticyclone and that over the Pacific. During the ensuing week high pressure areas continued to advance southward over the continent and the connection between the continental and oceanic HIGHS was for the most part maintained. The oceanic HIGH was steadily reinforced on its western side.

From the 15th to the 20th a belt of low pressure was established between the Aleutian LOW and the American mainland along which depressions of varying magnitude were irregularly distributed. About the 23d a break

occurred in the oceanic belt of high pressure, occasioned by a depression of some magnitude advancing eastward and southeastward from the western part of the ocean. It was this depression that gave rise to the principal gales of the month along the northern steamer lanes. By the 27th this area of low pressure had reached the Gulf of Alaska and the region southeastward therefrom where it lost energy and broke up into minor depressions.

On the 29th a fresh disturbance appeared at Dutch Harbor, occasioning the lowest pressure of the month, 29.02 inches. On the same date the American steamship *Grays Harbor*, in latitude 50° 48′ N., longitude 168° 15′ W., reported a pressure of 28.90 inches, the lowest reading for the month thus far reported by any observing vessel.

The month closed with a pressure distribution quite similar to that at the beginning; that is, with the California-Pacific HIGH fairly well established in its normal position and a depression over the Aleutians.

The weather at Honolulu was warm and dry. East winds predominated, the average hourly velocity being 10.1 miles per hour, or 1.1 miles above the normal. The maximum velocity was 31 miles per hour, from the east, occurring on the 1st.

TYPHOONS AND DEPRESSIONS

By Rev. José Coronas, S. J.

[Weather Bureau, Manila, P. I.]

ONE TYPHOON OVER NORTHERN LUZON IN MAY, 1930

There was only one typhoon over the Philippines during this month of May. It followed a track quite proper to the month, traversing the Archipelago twice, once moving westward, and then, in its movement to the east after it recurved to north, northeast and east, passed to the west and northwest of northern Luzon.

The observations received up to June 6 do not show that this typhoon was very deep in any part of its track, yet it caused considerable damage by the long duration of squalls and rains in the western provinces of northern Luzon.

The typhoon appeared for the first time in our weather map of 6 a. m., May 19, near 144° longitude E. and 5° latitude N. It moved northwestward on the 19th and 20th, and passed over or very near Yap in the afternoon of the 20th. It moved much inclined to the north from the evening of the 20th until the night of the 21st to 22d when it took a westerly direction. Its center crossed northern Luzon not far north of Baguio in the evening and night of the 24th. Once in the China Sea it was noticed soon that the typhoon had a tendency to recurve northeastward. It moved northward on the 25th and advanced very slowly on the 26th and 27th, while inclining more and more to the northeast and east. Its center was then less than 100 miles to the northwest of Luzon. On the 28th the typhoon moved decidedly eastward across the Balintang Channel near to the south of Basco, but on the 29th it took again a northerly direction. Finally on the 31st it inclined again northwestward, and filled up gradually over the western part of the Eastern Sea on June 1 to 2.

The approximate position of the center at 6 a. m. May 19 to June 1, was as follows:

May 19, 6 a. m., 144° 00′ longitude E, 5° 20′ latitude N.
May 20, 6 a. m., 139° 45′ longitude E, 8° 10′ latitude N.
May 21, 6 a. m., 136° 45′ longitude E, 12° 30′ latitude N.
May 22, 6 a. m., 134° longitude E, 16° 20′ latitude N.
May 23, 6 a. m., 129° 20′ longitude E, 17° 15′ latitude N.
May 24, 6 a. m., 125° longitude E, 17° 30′ latitude N.
May 25, 6 a. m., 118° 55′ longitude E, 17° latitude N.
May 26, 6 a. m., 119° 30′ longitude E, 19° 10′ latitude N.
May 27, 6 a. m., 119° 50′ longitude E, 19° 35′ latitude N.
May 28, 6 a. m., 120° 15′ longitude E, 19° 50′ latitude N.
May 29, 6 a. m., 124° longitude E, 20° 25′ latitude N.
May 30, 6 a. m., 125° 05′ longitude E, 23° 50′ latitude N.
May 31, 6 a. m., 125° 05′ longitude E, 26° 05′ latitude N.
June 1, 6 a. m., 124° 30′ longitude E, 27° 15′ latitude N.

The American steamers *President McKinley*, *Tacoma*, and *President Taft* were well under the influence of this typhoon over the China Sea to the northwest, west and south of the center. A gale from W. (8) and WSW. (9), respectively, were reported by the steamers *President McKinley* and *Tacoma* on the 25th.

Besides this typhoon there was another depression or typhoon, of not much importance for the Philippines, over the China Sea. It moved northwestward from the Paracels on the 17th, crossed Hainan on the 18th, and entered the Continent on the 19th north of Gulf of Tongking.

FALL OF PUMICE

Mr. P. E. Troup, second officer and observer on the steamship *American Dragon*, Capt. C. H. Bruun, San Francisco toward Shanghai, reports a fall of pumice, as follows:

May 12, 2.30 a. m.: Approximate position, latitude 48° 53′ N., longitude 172° 16′ W. Noticed a strong peculiar smell of gas; sky overcast with a fresh west by north breeze. At daylight ship was covered with a fine ash. The peculiar smell lasted till about noon.

The following note in regard to this occurrence is taken from the Hydrographic Bulletin of June 18, 1930:

H. B. Metcalfe, an officer of the British steamer *Empress of Russia*, Capt. A. J. Holland, reports that May 13, 1930, in latitude 51° 06′ N., longitude 178° 33′ W., extensive fields of floating pumice were encountered, which appeared to be about 2 inches deep in the larger fields, and ranged from the size of a pinhead to that of a large bean. Some of the patches were from 2 to 3 acres in extent, while others were much smaller, and reached north and south as far as could be seen. The vessel passed through continuous patches for 30 miles.

CLIMATOLOGICAL TABLES

(For description of tables and charts, see REVIEW, January, 1930, p. 37)

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, May, 1930

Section	Temperature		Monthly extremes						Precipitation		Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	72.9	+1.6	5 stations	95	[1] 5	Valley Head	40	30	3.82	−0.15	St. Bernard	10.59	Alaga	0.35
Arizona	62.0	−4.5	Parker	108	21	Spring Valley	10	11	0.94	+0.59	2 stations	2.91	Parker	0.05
Arkansas	68.8	−0.2	Dumas	95	27	Dutton	34	31	10.06	+5.04	Hot Springs	18.51	Corning (river)	3.86
California	56.7	−3.7	Greenland Ranch	110	19	Ellery Lake	8	8	1.46	+0.37	Cuyamaca	8.80	Madeline	T.
Colorado	50.2	−1.9	4 stations	95	[1] 21	2 stations	2	[1] 6	2.40	+0.61	Julesburg	7.74	Nast	0.10
Florida	76.6	+1.0	2 stations	99	[1] 17	3 stations	52	[1] 3	4.19	+0.21	Venus	12.64	Bonifay	0.20
Georgia	73.6	+2.0	do	98	[1] 19	Toccoa	43	31	2.26	−1.24	Clayton	7.95	Fitzgerald	0.10
Idaho	51.7	−1.0	Orofino	97	27	2 stations	16	[1] 21	2.11	+0.50	Wallace	4.92	Cronks Canyon	0.10
Illinois	64.2	+1.6	Mount Carmel	92	8	Freeport	30	17	1.84	−2.16	Galena	4.53	Tuscola	0.21
Indiana	63.6	+1.4	2 stations	94	[1] 5	3 stations	31	[1] 29	1.79	−2.22	Hobart	3.61	Bedford	0.60
Iowa	60.2	+0.1	do	91	27	Sanborn	26	17	3.71	−0.87	Corning	7.20	Columbus Junction	1.61
Kansas	62.6	−0.8	Lincoln	98	27	Goodland	29	18	4.36	+0.57	Wellington	8.65	Richfield	1.35
Kentucky	66.6	+1.3	Williamstown	94	6	Williamsburg	33	31	2.99	−1.11	Burnside	6.38	Grant	0.53
Louisiana	74.5	+0.9	Lake Providence	93	28	2 stations	47	[1] 25	5.86	+1.43	Lake Providence	13.66	Port Eads	0.42
Maryland-Delaware	64.9	+2.3	5 stations	96	7	do	27	[1] 4	2.21	−1.38	Milford, Del	5.38	Keedysville, Md	0.73
Michigan	56.3	+2.5	Saranac	93	9	Wolverine	16	27	2.98	−0.14	Iron River (near)	5.89	Northport	0.65
Minnesota	54.9	+0.4	Red Lake Falls	94	21	Itasca State Park	18	17	4.13	+1.09	New London	6.89	Grand Marais	2.07
Mississippi	72.9	+1.2	Aberdeen	95	28	2 stations	45	31	9.22	+4.78	Moorhead	19.70	Merrill	1.87
Missouri	64.7	+0.3	Louisiana	95	21	Louisiana	33	30	3.43	−1.24	Hailey	7.38	Farmington	0.97
Montana	51.4	+0.3	White Sulphur Springs	96	27	Lewistown	17	23	1.26	−0.88	Heron	4.26	Melstone	0.05
Nebraska	57.4	−1.7	Newport	95	26	2 stations	27	18	5.10	+1.57	Central City	10.35	Butte	2.01
Nevada	52.5	−3.7	2 stations	101	28	do	15	8	2.20	+1.34	Beowawe	7.44	Searchlight	0.30
New England	56.5	+1.6	Fitchburg, Mass	96	7	do	25	[1] 10	3.63	+0.23	Pittsburg (a), N. H	7.34	Machias, Me	1.18
New Jersey	62.7	+2.6	Flemington	98	7	Belleplain	31	12	2.75	−0.98	Chatham	4.50	Bridgeton	1.54
New Mexico	56.5	−2.5	Carlsbad	103	21	Selsor Ranch	5	6	1.16	−0.01	Roy	5.12	6 stations	0.00
New York	57.7	+2.0	3 stations	96	7	Indian Lake	22	12	3.63	+0.11	Raquette Lake	6.17	Buffalo	1.17
North Carolina	68.3	+2.4	Goldsboro	96	19	Mount Mitchell	25	31	3.06	−0.99	Highlands	7.54	Beaufort	0.47
North Dakota	50.8	−1.8	Park River	98	21	Eckman	18	[1] 16	2.62	+0.07	Larimore	5.99	Beach	0.96
Ohio	62.8	+2.7	Circleville	97	9	Millport	29	30	1.80	−1.82	St. Paris	3.59	2 stations	0.72
Oklahoma	67.5	−0.4	Goodwell	97	21	3 stations	34	[1] 12	6.36	+1.68	Tuskahoma	13.57	Goodwell	0.57
Oregon	51.8	−1.6	Umatilla	92	27	Crater Lake	5	7	2.23	+0.42	Welches	8.05	Arlington	T.
Pennsylvania	61.2	+1.7	Phoenixville	99	7	2 stations	25	[1] 27	3.03	−0.96	Phoenixville	6.39	Meadville	1.03
South Carolina	72.0	+1.1	Greenwood	96	5	Walhalla	38	31	2.44	−1.17	Walhalla	6.56	Marion	0.50
South Dakota	54.8	−0.8	Tyndall	96	20	Redfield	20	17	2.89	−0.32	St. Francis	9.26	Rapid City	0.92
Tennessee	68.0	+1.3	2 stations	94	6	Crossville	36	[1] 25	5.68	+1.45	Brownsville	11.53	Celina	2.75
Texas	72.6	−0.5	Fort McIntosh	105	6	2 stations	32	[1] 11	5.15	+1.49	Winfield (near)	18.40	Kent	0.00
Utah	52.4	−3.1	St. George	95	28	Panguitch	10	9	1.68	+0.38	Lewiston	3.34	Loa	T.
Virginia	66.8	+3.3	Winchester	98	7	Burkes Garden	29	4	2.41	−1.33	Dante	12.53	Deerfield	0.29
Washington	53.1	−0.9	Wahluke	91	13	Davenport	18	7	2.27	+0.11	Mount Baker Lodge	9.28	Toppenish	0.06
West Virginia	63.3	+1.3	Romney	101	7	Pickens	23	26	2.17	−1.74	Rowlesburg	4.99	Wardensville	0.64
Wisconsin	56.6	+1.9	2 stations	93	[1] 6	Rest Lake	13	28	3.48	−0.35	Park Falls	5.51	Williams Bay	1.78
Wyoming	48.7	−0.3	Powell	93	30	2 stations	8	11	2.32	+0.18	Middle Fork (near)	6.35	Lovell	0.51
Alaska [April]	28.4	−0.4	Sitka	66	21	Barrow	−38	6	1.42	−0.26	Ketchikan	9.00	Barrow	0.01
Hawaii	72.2	+0.2	Kaanapali (Maui)	90	31	Volcano Observatory	49	4	5.02	−1.36	Papaikou (Mauka)		12 stations	0.00
Porto Rico	77.4	+0.2	Utuado	96	5	Guineo Reservoir	47	21	4.75	−1.80	Lares	15.52	Santa Rita	0.81

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1930*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F.	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							56.8	+2.2										69	3.53	+0.4										6.0		
Eastport	76	67	85	29.82	29.90	−0.06	49.2	+1.5	76	7	57	37	21	41	33	43	38	72	1.26	−1.8	13	6,744	s.	33	e.	26	4	10	17	7.4	0.0	0.0
Greenville, Me	1,070	6	----	28.76	29.92	----	51.2	----	82	2	62	30	12	40	48	----	----	----	5.17	----	21	4,641	nw.	24	----	4	6	7	18	----	0.0	0.0
Portland, Me	103	82	117	29.82	29.94	−.03	55.0	+1.7	88	6	63	41	31	47	43	48	43	69	4.95	+1.6	16	5,804	nw.	27	n.	4	9	10	12	5.7	0.0	0.0
Concord	289	70	79	29.63	29.94	−.04	56.8	+2.5	89	7	68	35	11	45	42	----	----	----	2.92	−0.1	13	4,101	nw.	23	nw.	4	10	8	13	5.9	0.0	0.0
Burlington	403	11	48	29.51	29.94	−.03	56.0	−0.5	86	23	65	39	31	47	35	----	----	----	5.18	+2.3	20	5,987	s.	31	s.	2	5	9	17	7.4	0.0	0.0
Northfield	876	12	60	----	29.95	−.02	54.2	+1.4	87	23	65	30	11	43	47	----	----	68	3.80	+1.0	16	4,066	s.	28	nw.	4	3	15	13	7.0	0.0	0.0
Boston	125	106	165	29.80	29.94	−.04	59.4	+2.3	95	7	68	45	20	50	32	51	44	62	3.39	+0.2	11	5,748	nw.	36	nw.	7	8	11	12	5.8	0.0	0.0
Nantucket	12	14	90	29.93	29.94	−.05	54.6	+2.3	77	6	62	42	12	48	26	50	47	79	2.03	−0.8	9	9,829	sw.	42	e.	15	10	13	8	5.2	0.0	0.0
Block Island	26	11	46	29.91	29.94	−.05	56.8	+4.0	79	6	64	46	11	50	26	50	47	76	3.06	−0.4	9	11,112	sw.	43	e.	15	8	15	8	5.6	0.0	0.0
Providence	160	215	251	29.78	29.95	−.03	60.2	+1.7	94	7	70	42	31	50	34	51	43	58	2.21	−0.8	11	8,108	nw.	40	nw.	3	16	5	10	4.6	0.0	0.0
Hartford	159	122	----	29.78	29.96	−.02	61.1	+3.6	93	7	72	43	11	51	32	----	----	----	4.57	+1.0	14	----	nw.	----	----	----	10	10	11	5.7	0.0	0.0
New Haven	106	74	153	29.85	29.96	−.03	61.4	+3.5	95	23	71	42	31	52	37	54	50	69	5.45	+1.8	13	5,848	nw.	29	nw.	4	14	8	9	5.3	0.0	0.0
Middle Atlantic States							64.7	+2.6										63	2.56	−0.9										4.8		
Albany	97	107	115	29.86	29.96	−.02	60.6	+1.3	92	7	70	42	30	51	35	53	47	67	3.02	+0.1	11	4,731	s.	25	sw.	3	16	4	11	4.6	0.0	0.0
Binghamton	871	10	84	29.07	30.00	+.02	59.2	+1.8	90	23	70	38	21	48	41	----	----	----	4.18	+0.9	14	3,851	nw.	24	nw.	3	9	10	12	5.7	0.0	0.0
New York	314	414	454	29.64	29.97	−.02	62.6	+2.0	89	23	71	44	26	54	30	53	46	59	2.89	−0.4	9	10,867	nw.	50	nw.	3	6	13	12	6.3	0.0	0.0
Bellefonte	1,050	5	36	28.90	30.00	----	58.4	----	90	7	72	32	27	45	50	52	46	65	1.88	----	8	----	sw.	----	----	----	8	11	12	5.6	0.0	0.0
Harrisburg	374	94	104	29.62	30.01	+.03	63.8	+2.0	91	7	74	45	27	54	36	54	47	58	2.62	−0.8	7	4,802	w.	25	sw.	2	12	13	6	4.7	0.0	0.0
Philadelphia	114	123	367	29.88	30.01	+.02	66.4	+3.5	94	7	76	47	26	57	29	57	51	62	3.25	0.0	8	9,141	nw.	38	sw.	2	11	14	6	4.7	0.0	0.0
Reading	325	81	98	29.65	30.00	----	63.9	+1.4	93	7	75	44	27	53	35	54	46	56	3.69	0.0	9	4,340	w.	20	nw.	24	14	10	7	4.5	0.0	0.0
Scranton	805	111	119	29.15	30.00	+.02	60.1	+0.7	90	23	71	40	21	49	40	52	45	61	2.58	−0.7	12	4,903	sw.	29	sw.	2	9	11	11	5.6	0.0	0.0
Atlantic City	52	37	172	29.93	29.99	+.01	62.8	+4.7	90	6	71	44	31	55	28	55	50	68	1.95	−1.1	7	11,504	nw.	40	nw.	4	10	15	6	4.8	0.0	0.0
Cape May	17	13	49	----	----	----	63.8	+5.2	90	8	74	46	31	54	32	57	53	74	2.00	−1.0	9	----	nw.	----	----	----	16	8	7	----	0.0	0.0
Sandy Hook	22	10	55	29.94	29.96	----	62.0	----	89	7	70	47	26	54	29	54	49	67	1.83	−1.9	8	9,572	w.	35	s.	2	11	11	9	5.3	0.0	0.0
Trenton	190	159	183	29.78	29.98	----	63.[illegible]	+2.3	93	7	74	42	31	53	32	54	46	58	1.99	−1.1	8	7,230	nw.	35	sw.	14	12	10	8	4.9	0.0	0.0
Baltimore	123	100	215	29.88	30.00	+.01	68.4	+4.0	96	7	79	46	26	58	35	57	49	55	2.91	−0.6	5	7,227	sw.	32	nw.	24	14	12	5	4.4	0.0	0.0
Washington	112	62	85	29.90	30.02	+.02	67.3	+3.6	95	7	78	45	26	56	43	56	48	56	1.81	−1.9	8	4,252	nw.	25	nw.	24	14	12	5	4.3	0.0	0.0
Cape Henry	18	8	54	30.00	30.02	----	68.6	+4.4	93	7	77	53	27	60	35	61	56	70	2.88	−0.7	7	7,948	sw.	42	n.	24	13	9	9	4.4	0.0	0.0
Lynchburg	681	153	188	29.31	30.04	+.04	68.4	+1.1	92	8	80	45	26	56	37	59	53	61	1.75	−1.9	8	4,857	w.	30	sw.	5	14	11	6	4.4	0.0	0.0
Norfolk	91	170	205	29.94	30.04	+.04	69.0	+2.8	91	8	79	50	31	59	34	59	53	63	1.63	−2.2	6	8,386	sw.	37	n.	24	11	10	10	4.6	0.0	0.0
Richmond	144	11	52	29.88	30.03	+.04	68.8	+2.3	92	7	80	47	31	57	42	59	52	59	2.71	−1.1	9	5,029	sw.	25	w.	28	16	10	5	3.5	0.0	0.0
Wytheville	2,304	49	55	27.70	30.04	+.05	62.1	+0.7	85	5	74	39	26	51	39	55	50	69	2.45	−1.2	14	3,604	w.	23	sw.	28	13	11	7	4.5	0.0	0.0
South Atlantic States							72.3	+2.1										70	2.20	−1.3										5.3		
Asheville	2,253	70	84	27.75	30.07	+.08	63.8	+1.2	84	5	74	42	31	54	32	57	53	74	2.56	−0.9	14	4,198	nw.	32	se.	19	10	12	9	5.4	0.0	0.0
Charlotte	779	55	62	29.23	30.06	+.07	71.9	+3.0	90	5	82	48	31	62	30	61	56	64	3.08	−0.6	8	2,440	s.	26	nw.	13	10	7	14	5.7	0.0	0.0
Greensboro	886	5	56	29.12	30.06	----	68.2	----	90	5	81	42	26	56	39	60	56	69	6.04	----	8	5,320	sw.	31	w.	6	12	8	11	5.1	0.0	0.0
Hatteras	11	5	50	30.04	30.04	+.03	70.4	+1.7	85	20	77	54	22	64	24	67	64	81	1.96	−1.8	6	8,655	sw.	37	n.	30	16	6	9	4.4	0.0	0.0
Raleigh	376	103	110	29.65	30.04	+.05	70.8	+2.3	91	8	81	46	31	60	32	62	56	65	2.02	−1.8	8	4,043	sw.	25	ne.	29	11	8	12	5.3	0.0	0.0
Wilmington	78	81	91	29.99	30.07	+.06	72.4	+1.6	89	20	81	50	31	64	25	66	63	77	1.51	−1.9	6	4,730	sw.	18	w.	28	12	12	7	4.7	0.0	0.0
Charleston	48	11	92	30.03	30.08	+.07	75.0	+2.3	92	20	82	54	31	68	21	68	65	76	0.76	−2.2	6	6,252	sw.	24	n.	30	11	7	13	5.3	0.0	0.0
Columbia, S. C	351	41	57	29.69	30.07	+.07	73.8	+1.9	92	28	84	50	31	64	29	63	58	65	2.95	−0.1	9	4,201	s.	30	sw.	13	11	9	11	5.2	0.0	0.0
Due West	711	10	55	29.33	20.10	----	71.3	----	91	3	82	49	31	61	30	----	----	----	2.31	----	13	5,264	sw.	26	w.	19	8	8	15	6.0	0.0	0.0
Greenville, S. C	1,039	139	146	28.97	30.06	----	70.6	+3.4	88	5	80	52	31	61	28	61	56	66	2.27	−1.8	9	5,287	w.	29	w.	15	8	9	14	6.0	0.0	0.0
Augusta	182	62	77	29.86	30.05	+.06	75.2	+2.8	92	18	86	50	31	64	30	65	59	62	1.44	−1.6	6	3,559	s.	23	nw.	8	8	14	9	5.3	0.0	0.0
Savannah	65	150	194	30.00	30.07	+.07	75.4	+2.0	92	20	84	54	31	67	28	67	63	73	1.94	−1.1	6	6,691	s.	27	n.	30	9	10	12	5.5	0.0	0.0
Jacksonville	43	209	245	30.02	30.07	+.07	75.7	+0.7	92	18	83	62	31	68	24	68	64	74	3.70	−0.3	9	6,549	e.	28	ne.	31	9	12	10	5.4	0.0	0.0
Florida Peninsula							78.7	+1.5										74	6.09	+1.8										5.1		
Key West	22	10	64	29.98	30.00	+.03	79.8	+0.7	87	21	85	69	1	75	14	73	71	75	3.23	−0.3	8	6,633	se.	26	sw.	30	13	12	6	4.7	0.0	0.0
Miami	25	124	168	30.01	30.04	+.04	78.6	+2.2	86	17	83	68	2	74	16	72	69	73	8.85	+2.6	11	7,057	e.	32	sw.	30	7	15	9	5.6	0.0	0.0
Tampa	35	79	197	30.01	30.04	+.05	77.8	+1.5	92	21	87	63	23	68	26	70	66	74	6.20	+3.2	5	6,708	se.	50	ne.	23	10	13	8	5.3	0.0	0.0
Titusville	44	5	----	30.01	30.06	----	78.3	----	94	20	88	61	3	69	28	----	----	----	6.49	----	10	----	e.	----	----	----	11	11	9	4.7	0.0	0.0
East Gulf States							73.6	+1.1										70	4.60	+0.8										5.4		
Atlanta	1,173	190	216	28.85	30.07	+.08	70.4	+0.5	88	5	79	53	31	62	25	61	56	66	6.50	+3.0	14	5,697	nw.	26	nw.	24	8	10	13	6.1	0.0	0.0
Macon	370	78	87	29.67	30.06	+.07	73.9	+1.6	91	28	85	52	31	63	32	64	58	62	1.05	−1.9	8	3,632	s.	19	w.	19	13	7	11	5.0	0.0	0.0
Thomasville	273	49	103	29.76	30.05	+.06	76.1	+2.1	91	5	87	60	2	65	27	66	61	66	1.29	−2.3	5	4,298	se.	19	sw.	23	5	15	11	5.9	0.0	0.0
Apalachicola	36	11	51	30.01	30.05	----	75.8	----	90	20	82	63	3	70	21	69	66	73	0.62	−2.8	4	5,843	se.	28	e.	27	15	13	3	3.7	0.0	0.0
Pensacola	56	149	185	29.99	30.05	+.06	74.4	+0.5	84	12	80	60	25	69	21	68	65	75	0.90	−2.5	3	8,169	s.	28	s.	16	9	12	10	5.8	0.0	0.0
Anniston	741	9	57	29.30	30.08	+.09	70.6	+2.2	91	4	82	46	31	59	35	----	----	----	7.91	+4.0	12	2,554	s.	13	w.	14	17	2	12	4.7	0.0	0.0
Birmingham	700	11	48	29.31	30.06	+.08	72.0	+0.9	90	5	82	49	31	62	30	63	58	67	7.94	+4.0	10	3,798	s.	20	s.	7	13	6	12	5.2	0.0	0.0
Mobile	57	125	161	29.98	30.04	+.05	74.6	+0.2	88	12	82	58	25	67	25	68	65	77	3.54	−0.8	5	6,856	s.	30	se.	6	3	16	12	6.4	0.0	0.0
Montgomery	223	100	112	29.81	30.06	+.07	74.9	+1.5	91	5	84	54	31	65	27	64	58	62	2.10	−1.7	6	3,961	s.	19	n.	30	9	8	14	5.9	0.0	0.0
Corinth	469	6	----	----	----	----	71.3	----	90	12	82	48	31	60	37	----	----	----	6.32	----	12	----	se.	----	----	----	8	18	5	----	0.0	0.0
Meridian	375	87	95	29.65	30.04	+.06	72.7	+1.4	88	7	82	53	31	63	29	65	60	70	8.54	+4.2	9	3,582	s.	26	sw.	17	9	9	13	5.7	0.0	0.0
Vicksburg	247	65	73	29.76	30.03	+.06	73.1	+0.2	87	8	82	55	31	64	27	65	62	74	10.54	+6.2	10	4,281	s.	24	sw.	23	11	12	8	4.9	0.0	0.0
New Orleans	53	76	84	29.97	30.02	+.05	76.5	+1.1	88	18	84	60	31	69	20	69	66	77	4.31	−0.3	4	4,777	se.	22	ne.	16	9	13	9	5.7	0.0	0.0
West Gulf States							72.7	−0.7										78	7.15	+3.1										6.3		
Shreveport	249	77	93	29.73	29.99	+.04	73.0	−0.6	87	22	81	57	31	65	26	66	62	73	6.42	+2.2	11	3,969	se.	19	w.	6	8	9	14	5.6	0.0	0.0
Bentonville	1,303	11	44	28.60	29.94	+.01	64.7	−1.7	82	8	75	43	31	54	33	----	----	----	5.82	----	13	3,940	s.	40	se.	8	21	5	5	----	0.0	0.0
Fort Smith	457	79	94	29.49	29.96	+.03	68.8	−0.8	87	21	78	50	24	59	28	62	58	72	7.44	+2.6	14	5,218	e.	36	nw.	22	13	7	11	5.0	0.0	0.0
Little Rock	357	136	153	29.63	29.99	+.04	69.9	−0.4	85	28	78	54	31	62	25	63	58	71	11.12	+6.3	14	5,447	s.	29	e.	10	13	5	13	5.3	0.0	0.0
Austin	605	136	148	29.30	29.93	----	73.1	−1.5	88	19	81	52	7	65	32	68	65	79	8.97	+4.3	12	5,097	se.	34	n.	18	5	11	15	6.6	0.0	0.0
Brownsville	57	83	100	29.84	29.90	----	78.6	0.0	92	18	84	67	24	73	21	74	72	88	5.07	+2.8	10	8,730	se.	32	se.	16	2	11	18	7.6	0.0	0.0
Corpus Christi	20	11	78	29.90	29.92	+.02	77.1	+0.9	90	18	81	66	24	73	18	73	71	86	4.37	+1.2	11	9,737	se.	44	se.	9	1	7	23	8.3	0.0	0.0
Dallas	512	220	227	29.40	29.94	----	70.7	----	85	29	78	56	23	63	23	----	----	----	11.23	+6.8	14	8,589	se.	57	se.	6	15	8	8	4.2	0.0	0.0
Fort Worth	670	106	114	29.23	29.93	+.02	71.2	−1.1	88	29	80	55	24	63	27	65	61	74	10.37	+5.7	14	6,690	se.	39	se.	6	8	7	16	6.5	0.0	0.0
Galveston	54	106	114	29.93	29.99	+.05	75.5	+0.7	84	23	79	64	19	72	15	71	69	84	2.69	−0.7	9	8,964	se.	39	se.	10	4	12	15	7.2	0.0	0.0
Groesbeck	461	11	56	29.47	29.95	----	71.3	----	86	29	79	54	25	64	24	----	----	----	9.93	+5.9	12	6,743	se.	31	w.	6	8	7	16	6.4	0.0	0.0
Houston	138	292	314	29.82	29.97	----	74.4	−1.1	87	7	81	59	25	68	23	----	----	----	6.00	+1.5	14	8,852	se.	38	se.	6	8	7	16	6.5	0.0	0.0
Palestine	510	64	72	29.45	29.98	+.05	71.2	−1.5	86	29	79	55	31	63	26	65	62	77	8.20	+3.7	9	4,787	s.	30	se.	6	10	6	15	6.3	0.0	0.0
Port Arthur	34	58	66	29.94	29.98	----	75.6	----	86	14	81	60	26	70	22	----	----	----	8.09	+4.0	12	5,648	se.	24	e.	11	7	7	17	6.4	0.0	0.0
San Antonio	693	119	132	29.20	29.92	+.02	75.0	−0.1	91	19	83	58	7	67	28	67	64	73	0.89	−2.3	15	5,167	se.	26	se.	5	4	11	16	7.4	0.0	0.0
Taylor	571	55	63	29.36	29.96	+.05	72.4	−1.9	88	22	80	55	7	64	29	----	----	----	6.48	+2.5	13	5,504	se.	28	se.	6	9	7	15	5.9	0.0	0.0

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TABLE 1.—*Climatological data for Weather Bureau stations, May, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							65.9	+1.0										64	2.64	-1.1										5.1		
Chattanooga	762	190	215	29.25	30.06	+0.07	68.4	-0.4	86	6	77	52	31	60	29	61	56	70	6.27	+2.5	17	4,615	sw.	30	sw.	18	11	9	11	5.7	0.0	0.0
Knoxville	995	102	111	29.02	30.06	+.07	68.5	+1.3	88	4	79	47	31	58	31	60	55	69	4.21	+0.5	13	4,155	sw.	22	s.	19	9	11	11	5.6	0.0	0.0
Memphis	399	76	97	29.60	30.01	+.05	70.6	0.0	86	22	78	53	24	63	26	63	59	70	5.86	+1.7	10	4,360	sw.	30	w.	10	12	9	10	4.7	0.0	0.0
Nashville	546	168	191	29.49	30.07	+.09	68.0	-0.2	88	4	77	51	30	60	28	61	56	67	5.23	+1.4	11	5,505	s.	35	sw.	8	13	8	10	4.7	0.0	0.0
Lexington	989	193	230	29.02	30.07	+.08	65.4	+1.1	88	6	75	45	31	56	32				3.35	-0.5	8	8,147	sw.	32	sw.	7	14	9	8	4.2	0.0	0.0
Louisville	525	188	234	29.48	30.06	+.08	67.2	+0.6	88	6	77	48	31	58	33	58	52	63	1.46	-2.3	10	6,616	s.	34	sw.	2	14	12	5	4.3	0.0	0.0
Evansville	431	76	116	29.57	30.03	+.06	67.8	+1.1	85	8	77	48	31	59	28	59	52	62	1.02	-2.8	10	6,090	s.	36	sw.	7	10	9	12	5.4	0.0	0.0
Indianapolis	822	194	230	29.14	30.02	+.05	64.1	+1.2	85	6	74	42	29	55	29	55	49	62	1.69	-2.2	10	7,493	s.	33	w.	2	11	13	7	4.9	0.0	0.0
Royal Center	736	11	55	29.22	30.02		61.0		84	9	71	36	29	51	33				2.03	-2.0	12	7,109	s.	36	w.	2	11	8	12	5.6	0.0	0.0
Terre Haute	575	96	129	29.40	30.01		65.0		86	8	75	43	31	55	34	56	50	62	1.28	-2.6	10	6,484	s.	32	w.	2	13	6	12	5.2	0.0	0.0
Cincinnati	627	11	51	29.37	30.04	+.05	65.4	+2.3	89	6	76	42	31	55	33	57	50	62	1.01	-2.7	8	4,462	s.	27	w.	23	13	9	9	4.6	0.0	0.0
Columbus	822	179	222	29.17	30.04	+.06	64.4	+2.1	89	6	74	42	31	54	31	55	48	60	1.04	-2.6	13	6,372	s.	43	nw.	5	10	12	9	5.3	0.0	0.0
Dayton	899	137	173	29.08	30.03		64.8	+2.2	88	6	74	43	31	55	31	56	50	62	2.64	-1.0	9	5,895	sw.	33	w.	2	13	12	6	4.4	0.0	0.0
Elkins	1,947	59	67	28.03	30.05	+.05	60.0	+0.8	86	10	72	31	26	48	43	53	48	68	1.98	-2.1	11	3,363	w.	25	nw.	28	7	14	10	6.2	0.0	0.0
Parkersburg	637	77	82	29.41	30.07	+.08	65.6	+1.8	90	10	77	39	26	54	35	56	49	59	1.29	-2.1	8	3,612	sw.	24	nw.	19	12	8	11	5.3	0.0	0.0
Pittsburgh	842	353	410	29.14	30.03	+.04	63.0	+0.6	88	9	73	37	30	53	34	54	48	63	1.05	-1.3	11	6,712	sw.	36	sw.	2	14	7	10	5.1	0.0	0.0
Lower Lake Region							59.1	+1.7										69	2.50	-0.7										5.4		
Buffalo	767	247	280	29.16	29.99	+.02	54.1	-0.5	83	23	62	35	30	46	28	49	45	74	1.17	-1.9	10	11,336	sw.	52	sw.	2	11	10	10	5.0	0.0	0.0
Canton	448	10	61	29.46	29.93		56.0	-0.2	85	23	66	33	18	46	31				3.10	+0.1	16	6,843	sw.	36	sw.	2	6	13	12	6.1	0.0	0.0
Ithaca	836	5	100	29.09	29.99		57.8	+0.3	88	23	68	38	21	47	39	51	46	67	3.49	+0.1	13	6,046	nw.	34	nw.	3	7	10	14	6.2	0.0	0.0
Oswego	335	76	91	29.61	29.98	+.01	55.0	-0.2	84	23	64	39	31	46	34	51	47	73	2.83	-0.2	16	6,159	w.	24	nw.	2	9	11	11	5.8	0.0	0.0
Rochester	523	86	102	29.43	30.00	+.03	59.0	+1.9	90	23	68	37	31	50	29	52	46	64	2.53	-0.4	14	6,598	w.	33	w.	1	12	10	9	4.8	0.0	0.0
Syracuse	596	65	79	29.34	29.99	+.01	60.1	+2.8	90	23	69	38	31	51	30				3.39	+0.4	15	5,091	w.	28	w.	3	11	8	12	5.6	0.0	0.0
Erie	714	130	166	29.25	30.01	+.03	60.0	+3.2	86	23	68	40	27	52	24	54	50	73	1.61	-1.8	13	8,569	sw.	40	sw.	2	15	10	6	4.2	0.0	0.0
Cleveland	762	267	337	29.20	30.02	+.04	61.8	+3.9	86	23	69	42	18	54	25	53	46	61	1.87	-1.2	15	8,789	w.	44	sw.	2	10	11	10	5.3	0.0	0.0
Sandusky	629	5	67	29.34	30.02	+.04	61.8	+2.6	88	23	71	42	26	53	34				2.79	-0.4	14	5,852	s.	29	sw.	2	6	16	9	5.9	0.0	0.0
Toledo	628	208	243	29.34	30.02	+.05	61.5	+2.1	86	6	70	40	30	53	31	53	48	64	1.05	-2.4	9	8,880	sw.	43	sw.	2	12	13	6	4.6	0.0	0.0
Fort Wayne	856	113	124	29.09	30.02		61.6	+1.4	87	10	71	40	29	52	36	54	49	67	2.99	-0.9	13	6,094	sw.	29	sw.	2	13	5	13	5.5	0.0	0.0
Detroit	730	218	258	29.23	30.02	+.05	61.0	+3.0	87	23	70	40	30	52	35	55	51	76	3.15	-0.1	14	6,548	w.	42	w.	2	9	12	10	5.4	0.0	0.0
Upper Lake Region							54.9	+2.1										70	2.50	-0.7										5.6		
Alpena	609	13	92	29.32	29.99	+.02	54.1	+3.6	90	22	64	33	18	44	36	48	42	68	3.67	+0.6	17	7,653	nw.	44	nw.	23	9	11	11	5.8	0.0	0.0
Escanaba	612	54	60	29.30	29.96	-.01	51.2	+1.6	80	1	60	29	17	43	37	46	41	70	2.46	-0.5	13	6,641	s.	34	nw.	2	10	12	9	5.2	0.0	0.0
Grand Haven	632	54	89	29.30	29.98	+.02	55.0	+0.5	88	10	63	35	25	46	32	49	44	71	1.61	-1.6	14	8,006	s.	30	s.	1	8	9	14	6.3	0.0	0.0
Grand Rapids	707	70	87	29.24	30.01	+.04	59.8	+1.8	88	9	70	35	30	50	32	51	45	63	2.39	-1.0	14	8,354	sw.	54	sw.	2	8	12	11	6.0	0.0	0.0
Houghton	668	64	99	29.21	29.94	-.03	51.4	+1.9	90	21	61	32	17	42	36				2.04	-1.0	14	7,253	e.	32	w.	2	5	13	13	6.4	0.5	0.0
Lansing	878	6	49	29.06	30.00		57.8	+0.9	86	9	68	34	30	47	34	53	49	76	3.36	-0.1	14	3,006	sw.	29	nw.	2	9	15	7	5.1	0.0	0.0
Ludington	637	60	66	29.28	29.98		53.6	+1.4	86	10	62	35	25	45	30	49	44	72	1.51	-1.5	10	6,830	s.	32	s.	1	12	11	8	4.6	T.	0.0
Marquette	734	77	111	29.15	29.96	-.01	52.0	+3.0	88	5	62	31	26	42	38	47	41	69	2.44	-0.5	14	6,569	w.	37	nw.	2	5	12	14	6.5	0.3	0.0
Port Huron	638	70	120	29.31	30.00	+.03	57.6	+2.4	83	6	67	36	27	48	33	52	48	74	2.82	-0.2	14	6,943	ne.	37	w.	2	8	18	5	4.7	0.0	0.0
Sault Sainte Marie	614	11	52	29.28	29.98	+.03	51.8	+2.8	83	5	61	29	18	42	37	47	42	71	2.89	-0.1	10	6,169	nw.	43	nw.	2	15	12	4	3.8	T.	0.0
Chicago	673	7	131	29.27	30.00	+.04	61.2	+3.7	86	6	69	43	17	53	31	53	48	65	2.16	-1.4	11	7,525	sw.	29	sw.	5	7	16	8	5.7	0.0	0.0
Green Bay	617	109	141	29.29	29.95	.00	56.8	+1.9	86	5	66	31	17	48	35	50	45	66	1.94	-1.6	10	7,755	s.	42	w.	1	6	11	14	6.5	0.0	0.0
Milwaukee	681	125	221	29.24	29.98	+.02	56.8	+2.7	85	22	65	38	17	48	32	51	46	72	2.30	-1.0	8	8,785	sw.	40	nw.	1	7	13	11	6.0	0.0	0.0
Duluth	1,133	5	47	28.72	29.94	-.02	49.0	+1.7	78	1	58	27	17	40	41	43	38	71	3.47	+0.2	14	9,394	ne.	45	nw.	1	10	8	13	5.6	0.0	0.0
North Dakota							51.5	-2.6										65	2.40	-0.1										5.9		
Moorhead	940	50	58	28.88	29.89	-.05	53.4	-1.7	93	21	64	28	17	43	41	47	41	66	2.68	-0.2	14	6,744	s.	28	nw.	21	8	6	17	6.6	T.	0.0
Bismarck	1,674	8	57	28.12	29.90	-.02	51.5	-3.0	87	20	63	29	17	40	40	44	37	63	2.19	-0.1	9	8,026	n.	34	nw.	21	12	8	11	5.3	1.5	0.0
Devils Lake	1,478	11	44	28.33	29.91	-.03	49.9	-2.7	87	3	61	28	16	39	37	44	38	70	3.61	+1.6	12	8,206	n.	48	ne.	6	6	11	14	6.4	T.	0.0
Ellendale	1,457	10	56	28.34	29.90		52.1		89	21	63	26	17	41	39				2.25	-0.8	12	11,552	nw.	43	nw.	21	6	9	16	6.7	T.	0.0
Grand Forks	833	12	67				52.2		92	21	64	28	17	41	45	47			4.28		13		nw.	39	w.	21	15	7	9		T.	0.0
Williston	1,878	41	48	27.93	29.91	-.02	51.2	-2.8	86	3	63	27	16	40	36	44	36	60	1.29	-0.8	8	6,728	se.	34	nw.	22	14	10	7	4.5	2.5	0.0
Upper Mississippi Valley							62.0	+0.5										66	2.83	-1.2										5.3		
Minneapolis	918	102	208	28.91	29.88		58.4	+0.7	86	21	68	32	17	48	30				3.38	-0.3	11	8,461	se.	34	s.	11	7	9	15	6.2	0.0	0.0
St. Paul	837	236	261	29.00	29.90	-.04	57.6	-0.3	84	21	68	32	17	48	30				3.39	+0.1	11	9,212	se.	42	sw.	6	8	9	14	5.8	0.0	0.0
La Crosse	714	11	48	29.15	29.92	-.02	59.4	+0.1	87	21	70	32	17	49	35	53	47	66	2.55	-1.2	11	3,508	se.	21	nw.	1	7	11	13	6.1	0.0	0.0
Madison	974	70	78	28.92	29.97	+.01	58.2	+0.6	83	21	67	36	18	49	33	52	46	68	4.23	+0.4	14	6,125	se.	29	w.	1	8	11	12	5.8	0.0	0.0
Wausau	1,247	4	64	28.62	29.95		56.2		86	21	67	31	25	46	38				2.24	-1.4	7	4,904	s.	21	se.	7	7	7	17	6.5	0.0	0.0
Charles City	1,015	10	51	28.88	29.95	+.01	58.5	+0.7	87	21	69	32	17	48	33	52	47	68	5.63	+1.3	12	5,144	se.	23	sw.	21	12	7	12	4.8	0.0	0.0
Davenport	606	71	79	29.31	29.97	+.02	62.8	+1.5	88	21	73	39	18	53	33	54	48	64	2.13	-1.8	9	8,509	sw.	40	nw.	1	9	13	9	5.3	0.0	0.0
Des Moines	861	5	90	29.04	29.94	+.01	61.1	-0.2	87	21	71	38	17	51	33	54	49	67	3.36	-1.2	9	7,698	s.	36	nw.	1	9	6	16	5.9	0.0	0.0
Dubuque	700	81	96	29.21	29.95	.00	60.3	0.0	88	21	70	37	17	50	35	54	48	67	4.33	+0.1	12	4,875	se.	23	s.	7	11	11	9	5.2	0.0	0.0
Keokuk	614	64	78	29.31	29.96	+.04	63.8	0.0	89	21	74	38	17	54	30	56	50	64	2.18	-1.8	13	6,106	s.	37	sw.	7	15	7	9	4.5	0.0	0.0
Cairo	358	87	93	29.64	30.02	+.06	68.4	0.0	86	28	77	51	31	60	25	60	55	67	2.49	-1.2	10	5,269	s.	31	sw.	2	11	8	12	5.3	0.0	0.0
Peoria	609	11	45	29.33	30.00	+.04	63.3	+1.6	88	8	74	37	30	52	34	55	50	67	1.07	-3.0	12	4,770	s.	29	w.	1	14	7	10	4.5	0.0	0.0
Springfield, Ill	636	154	191	29.32	29.98	+.03	64.0	+0.8	87	8	74	40	30	54	29	56	49	62	1.65	-2.7	9	9,041	s.	42	s.	7	12	12	7	5.0	0.0	0.0
Hannibal	534	74	109	29.42	29.99	+.05	64.7	+1.1	89	21	75	40	31	54	36				2.08	-2.3	11	6,983	sw.	40	sw.	7	14	10	7	4.1	0.0	0.0
St. Louis	568	265	303	29.39	29.99	+.04	67.3	+0.4	88	8	76	46	30	58	27	58	51	61	1.69	-2.6	8	9,140	s.	50	sw.	7	15	10	6	4.0	0.0	0.0
Missouri Valley							60.6	-0.9										66	3.80	-0.2										5.0		
Columbia, Mo	784	6	84	29.15	29.98	+.04	64.2	-0.1	88	21	74	44	20	54	32				2.88	-1.6	11	5,539	s.	30	w.	1	13	10	8	4.5	0.0	0.0
Kansas City	963	161	181	28.92	29.95	+.03	63.9	-0.9	86	21	73	41	18	55	32	56	50	65	4.39	-0.3	9	7,400	s.	40	sw.	7	12	13	6	4.5	0.0	0.0
St. Joseph	967	11	49	28.91	29.94		63.2		86	21	73	41	18	54	36	55	50	67	4.45	+0.2	12	6,223	sw.	39	nw.	7	13	16	8	4.8	0.0	0.0
Springfield, Mo	1,324	98	104	28.61	30.00	+.07	63.8	-0.7	83	8	73	46	20	55	28	57	52	68	4.40	-0.8	12	7,282	s.	33	se.	6	19	8	4	2.7	0.0	0.0
Iola	984	11	50	28.91	29.95	+.03	63.9	-1.3	87	28	74	44	31	53	34				4.12	-0.6	10	4,578	s.	18	se.	6	14	10	7	4.4	0.0	0.0
Topeka	987	92	107				63.8	-0.5	88	27	74	43	17	54	36				3.89	-0.6	9	7,305	sw.	30	sw.	7	14	7	10	4.4	0.0	0.0
Lincoln	1,189	11	81	28.66	29.92	+.01	61.4	-0.3	88	21	72	39	17	51	35	55	50	71	3.10	-1.0	12	7,491	s.	36	n.	7	9	10	12	5.5	0.0	0.0
Omaha	1,105	115	122	28.76	29.93	+.01	61.6	-0.8	89	21	71	38	18	52	36	53	46	62	2.74	-1.0	10	5,504	s.	24	nw.	7	14	7	10	5.0	0.0	0.0
Valentine	2,598	47	54	27.22	29.92	+.02	54.3	-1.9	92	21	66	30	17	43	45	47	40	66	3.82	+1.0	14	7,846	n.	36	s.	31	6	11	14	6.3	5.5	0.0
Sioux City	1,135	94	164	28.72	29.93	+.01	59.6	-0.8	88	21	69	35	17	50	39	52	45	64	5.88	+1.8	10	9,438	nw.	52	s.	6	8	10	13	6.1	0.0	0.0
Huron	1,306	59	74	28.52	29.92	.00	55.4	-1.0	87	21	66	30	17	45	41	49	43	67	4.48	+1.5	10	7,653	nw.	33	s.	25	12	7	12	5.5	T.	0.0
Pierre	1,572	70	75	28.24	29.90	-.01	56.3	-1.7	94	21	67	32	17	46	42	48	40	60	1.68	-0.8	7	7,811	nw.	36	nw.	21	7	10	14	6.1	T.	0.0
Yankton	1,233	49	57	28.61	29.92	.00	58.6	-0.8	87	21	68	36	17	49	30				3.55	-0.3	12	6,265	nw.	26	s.	21	11	7	13	5.5	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Northern Slope							51.8	−0.9										60	2.51	+0.1										6.1		
Billings	3,140	5	----				55.1	----	86	2	71	28	10	39	52	----	----		0.42	----	5	----	nw.	----	----	----	6	14	11	----	0.0	0.0
Havre	2,505	11	44	27.26	29.88	−0.02	54.2	+0.8	84	2	66	31	16	42	42	44	34	53	0.88	−1.2	9	5,426	e.	31	nw.	24	7	14	10	5.7	T.	0.0
Helena	4,124	89	113	25.70	29.86	−.07	52.4	+0.8	83	28	64	31	11	41	40	43	35	56	0.80	−1.5	8	5,972	sw.	34	sw.	20	3	13	15	6.9	T.	0.0
Kalispell	2,973	48	56	26.83	29.87	−.01	51.3	−0.1	80	27	62	30	7	41	41	43	35	59	1.87	+0.4	13	4,417	nw.	25	sw.	29	10	16	5	5.4	0.0	0.0
Miles City	2,371	48	55	27.38	29.92	+.01	55.2	−1.5	85	20	66	35	10	44	38	45	36	54	1.30	−0.9	9	5,134	nw.	26	se.	29	7	16	8	5.6	0.0	0.0
Rapid City	3,259	50	58	26.55	29.95	+.05	52.6	−1.4	85	25	63	32	18	42	41	45	37	60	0.92	−2.6	9	6,310	n.	36	nw.	21	4	9	18	7.1	T.	0.0
Cheyenne	6,088	84	101	23.95	29.90	+.05	46.8	−3.5	78	21	58	20	18	36	40	41	36	73	4.95	+2.5	18	7,836	w.	36	nw.	21	5	11	15	6.9	10.3	0.0
Lander	5,372	60	68	24.54	29.85	−.03	50.7	−0.5	83	28	63	30	10	39	38	42	33	60	5.70	+3.4	10	4,097	w.	38	sw.	21	9	14	8	5.4	3.4	0.0
Sheridan	3,790	10	47	26.01	29.88	----	52.3	----	84	25	65	29	23	39	49	44	37	63	1.50	−1.2	12	4,174	nw.	34	se.	29	5	12	14	6.3	0.0	0.0
Yellowstone Park	6,241	11	48	----	29.88	−.03	46.5	−0.9	78	28	58	25	23	35	39	----	----	59	1.04	−1.1	8	5,649	sw.	34	sw.	20	4	11	16	----	0.2	0.0
North Platte	2,821	11	51	27.00	29.90	+.02	56.8	−1.9	92	26	68	33	17	46	41	48	42	66	6.10	+3.3	13	5,274	e.	28	n.	10	10	6	15	5.8	3.1	0.0
Middle Slope							61.3	−1.2										65	4.48	+0.9										4.8		
Denver	5,292	106	113	24.65	29.87	+.03	54.6	−1.6	87	21	67	30	18	43	42	44	34	54	1.07	−1.1	10	5,359	s.	34	se.	31	8	13	10	5.7	1.0	0.0
Pueblo	4,685	80	86	25.18	29.81	−.02	57.8	−1.4	88	21	71	31	11	44	42	46	35	54	2.12	+0.5	12	4,956	e.	36	s.	3	11	14	6	5.0	0.0	0.0
Concordia	1,392	50	58	28.48	29.94	+.03	62.2	−1.0	87	21	72	39	17	52	31	55	50	68	5.52	+1.3	15	6,003	s.	26	sw.	21	12	9	10	4.8	T.	0.0
Dodge City	2,509	11	51	27.35	29.92	+.05	61.8	−1.7	91	21	74	36	19	50	41	53	47	66	3.28	+0.4	8	6,914	se.	33	se.	21	18	5	8	3.7	0.0	0.0
Wichita	1,358	139	158	28.50	29.92	+.02	63.8	−1.3	86	28	73	44	18	55	26	57	52	72	5.02	+0.6	12	9,277	s.	35	s.	10	15	6	10	4.7	0.0	0.0
Broken Arrow	765	11	56	29.14	29.96	----	65.8	----	82	21	75	49	31	57	26	----	----	----	6.79	+2.0	11	9,186	s.	44	nw.	17	14	8	9	4.6	0.0	0.0
Oklahoma City	1,214	10	47	28.66	29.92	+.03	67.4	−0.3	87	27	77	48	19	58	28	62	57	74	7.53	+2.6	11	6,800	s.	40	sw.	6	11	7	13	5.3	0.0	0.0
Southern Slope							70.0	−0.6										57	2.09	−0.6										4.7		
Abilene	1,738	10	52	28.12	29.89	+.02	72.7	+0.7	93	22	84	48	24	62	34	61	54	61	5.39	+1.4	8	7,637	s.	51	sw.	6	12	6	13	5.5	0.0	0.0
Amarillo	3,676	10	49	26.21	29.88	+.04	64.6	+0.5	92	21	77	43	11	52	35	52	42	56	1.49	−1.3	8	7,173	s.	30	w.	10	15	13	3	3.5	0.0	0.0
Del Rio	944	64	71	28.90	29.87	+.02	76.6	−0.4	94	6	85	53	7	68	35	67	61	68	1.01	−1.9	8	6,941	se.	42	nw.	6	6	6	19	6.6	0.0	0.0
Roswell	3,566	75	85	26.28	29.83	+.01	66.0	−3.4	97	21	80	37	11	52	40	51	35	42	0.48	−0.6	5	6,678	s.	34	ne.	22	19	7	5	3.3	0.0	0.0
Southern Plateau							61.6	−3.8										38	0.62	+0.3										2.6		
El Paso	3,778	152	175	26.11	29.82	+.04	69.1	−2.4	95	21	82	38	6	56	38	49	26	28	0.62	+0.3	4	8,472	w.	44	w.	6	22	9	0	2.0	0.0	0.0
Santa Fe	7,013	38	53	23.20	29.81	.00	52.4	−3.3	80	21	65	29	10	40	34	40	25	39	0.41	−0.8	6	5,140	sw.	27	s.	31	10	12	9	4.6	T.	0.0
Flagstaff	6,907	10	59	23.29	29.83	+.05	45.4	−5.3	74	27	60	14	9	31	42	35	----	53	0.73	----	7	6,642	sw.	30	sw.	30	10	15	6	----	4.8	0.0
Phoenix	1,108	10	107	28.68	29.82	+.04	71.7	−3.3	101	20	86	46	4	57	39	53	34	33	1.31	+1.2	3	4,043	w.	23	sw.	30	22	5	4	2.4	T.	0.0
Yuma	141	9	54	29.69	29.84	+.05	72.0	−4.2	102	20	88	45	9	56	42	55	38	38	0.12	+0.1	1	4,285	w.	29	n.	22	25	6	0	1.4	0.0	0.0
Independence	3,957	6	27	25.86	29.86	+.02	58.8	−4.2	89	28	73	31	5	45	39	43	----	----	0.64	+0.5	3	----	nw.	----	----	----	16	4	11	----	0.0	0.0
Middle Plateau							53.5	−2.4										52	1.45	+0.5										5.3		
Reno	4,532	74	81	25.38	29.88	−.03	51.4	−2.2	82	26	64	29	7	39	43	41	31	53	0.43	−0.2	7	5,789	w.	34	w.	2	10	13	8	5.1	1.5	0.0
Tonopah	6,090	12	20	----	----	----	48.5	----	77	20	58	21	7	39	29	39	30	57	0.71	----	9	----	nw.									
Winnemucca	4,344	18	56	25.52	29.89	−.02	51.6	−2.3	84	27	65	28	22	38	40	42	34	61	2.54	+1.7	14	4,440	sw.	34	w.	20	9	9	13	5.9	1.8	0.0
Modena	5,473	10	43	24.51	29.81	−.04	49.2	−4.3	79	28	63	25	9	36	45	39	28	53	1.28	+0.5	9	8,645	sw.	41	sw.	29	8	10	13	5.6	1.2	0.0
Salt Lake City	4,360	163	203	25.50	29.83	−.03	56.5	−0.9	86	27	67	33	8	46	31	44	33	47	1.52	−0.4	8	5,739	s.	38	nw.	21	7	15	9	5.6	T.	0.0
Grand Junction	4,602	60	68	25.27	29.81	−.02	59.0	−2.1	89	29	72	30	10	46	40	44	30	42	1.50	+0.7	11	4,699	se.	47	sw.	31	13	13	5	4.4	0.2	0.0
Northern Plateau							55.3	−0.9										55	1.81	+0.3										6.3		
Baker	3,471	48	53	26.37	29.94	−.02	50.5	−1.2	83	27	62	31	10	39	40	42	34	57	1.74	+0.2	12	4,287	nw.	22	nw.	8	3	11	17	7.3	T.	0.0
Boise	2,739	78	86	27.05	29.90	−.04	55.8	−1.3	90	27	67	34	22	44	37	46	37	57	1.68	+0.2	12	3,904	nw.	29	se.	2	3	14	14	6.7	T.	0.0
Lewiston	757	40	48	29.10	29.91	−.05	58.5	−1.0	91	27	70	36	7	46	45	----	----	----	1.64	+0.1	9	2,301	e.	21	nw.	17	10	2	19	6.4	0.0	0.0
Pocatello	4,477	60	68	25.36	29.85	−.04	53.4	−0.4	83	27	65	32	8	42	36	43	33	54	1.31	−0.2	13	5,890	se.	37	sw.	21	7	14	10	5.7	0.8	0.0
Spokane	1,929	101	110	27.87	29.91	−.05	55.0	−0.5	85	27	66	33	7	44	37	45	36	55	1.63	+0.2	9	4,604	s.	22	sw.	6	8	8	15	5.9	0.0	0.0
Walla Walla	991	57	65	28.86	29.92	−.04	58.6	−1.0	84	27	69	37	7	48	36	48	38	51	2.85	+1.2	10	3,379	s.	19	w.	21	10	9	12	5.8	0.0	0.0
North Pacific Coast Region							53.4	−1.1										71	2.00	0.0										6.7		
North Head	211	11	56	29.83	30.06	+.03	49.8	−1.1	61	26	53	39	7	46	14	47	44	83	3.20	+0.2	17	11,177	n.	50	sw.	20	4	12	15	6.8	0.0	0.0
Port Angeles	29	8	53	----	30.03	----	49.3	----	64	27	57	34	8	42	25	----	----	----	0.60	−0.6	7	5,525	sw.	31	w.	30	12	9	10	----	0.0	0.0
Seattle	125	215	250	29.87	30.00	−.01	53.4	−1.1	73	26	61	39	7	46	28	48	44	74	2.41	+0.5	13	5,586	s.	32	s.	20	6	8	17	6.6	0.0	0.0
Tacoma	194	172	201	29.81	30.01	−.01	53.8	−0.3	74	13	62	37	8	45	31	----	----	----	2.22	+0.1	13	6,018	sw.	38	sw.	21	7	11	13	6.4	0.0	0.0
Tatoosh Island	86	9	53	29.92	30.02	+.01	49.4	−0.2	59	26	53	41	7	46	13	48	46	91	2.78	−1.2	14	8,204	w.	39	s.	20	4	10	17	7.2	0.0	0.0
Yakima	1,076	58	67	28.78	29.92	----	58.5	−0.5	82	13	70	36	7	46	35	46	32	42	0.41	−0.2	5	4,859	nw.	26	sw.	20	10	11	10	5.4	0.0	0.0
Medford	1,329	29	58	28.59	29.99	----	54.4	----	85	1	67	32	4	42	43	46	39	64	0.82	−0.4	9	----	nw.	31	nw.	7	5	8	18	7.0	7.0	0.0
Portland, Oreg.	153	68	106	29.87	30.03	.00	55.0	−1.9	78	12	64	37	4	46	31	49	44	70	3.08	+0.9	16	3,663	nw.	20	sw.	20	6	6	19	7.3	0.0	0.0
Roseburg	510	75	99	29.49	30.05	+.02	53.6	−2.4	81	1	64	35	8	43	39	47	42	70	2.45	+0.5	12	2,900	n.	25	sw.	20	4	9	18	6.7	0.0	0.0
Middle Pacific Coast Region							57.7	−2.1										70	0.94	−0.1										4.0		
Eureka	62	73	89	30.02	30.09	+.04	51.5	−0.5	62	27	56	40	7	47	15	48	46	82	1.04	−0.8	7	6,044	n.	28	n.	3	9	10	12	5.5	0.0	0.0
Red Bluff	330	5	58	29.57	29.93	−.02	63.1	−3.2	88	25	76	43	5	50	36	52	43	54	2.14	+1.0	6	4,130	se.	20	nw.	6	14	8	9	4.4	0.0	0.0
Sacramento	69	106	117	29.87	29.94	.00	60.2	−3.1	88	23	73	40	11	48	36	52	46	67	0.34	−0.4	4	6,048	s.	24	sw.	2	23	7	1	2.1	0.0	0.0
San Francisco	155	208	243	29.82	29.90	.00	56.1	−0.7	77	22	62	46	7	50	23	50	46	75	0.16	−0.6	2	6,656	w.	32	w.	3	15	14	2	3.7	0.0	0.0
San Jose	141	12	110	29.86	30.02	----	57.6	−3.1	84	23	69	38	8	46	38	----	----	----	1.01	+0.5	4	4,865	nw.	23	nw.	3	11	11	9	4.5	0.0	0.0
South Pacific Coast Region							61.7	−1.7										64	1.05	+0.6										3.7		
Fresno	327	89	98	29.59	29.94	+.02	63.2	−3.9	92	23	76	41	8	50	36	51	39	48	0.29	−0.2	3	5,650	nw.	29	nw.	20	19	8	4	3.1	0.0	0.0
Los Angeles	338	159	191	29.60	29.96	+.01	61.8	−0.4	88	23	70	47	8	53	30	53	47	65	1.04	+0.6	4	3,669	sw.	16	sw.	7	19	6	6	3.4	0.0	0.0
San Diego	87	62	70	29.87	29.96	+.01	60.0	−0.8	70	20	66	47	4	55	15	55	52	78	1.81	+1.5	8	4,902	w.	25	sw.	4	12	9	10	4.7	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.92	30.01	----	79.6	+1.0	90	28	85	72	22	74	17	----	----	----	3.00	−2.2	11	7,336	e.	30	e.	18	5	18	8	5.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97	[1]29.74	[1]29.83	.00	79.5	−1.2	92	3	87	70	22	74	17	----	----	[2]86	9.70	+1.9	19	4,404	nw.	28	nw.	10	0	8	23	8.0	0.0	0.0
Cristobal	36	6	97	[1]29.81	[1]29.84	.00	81.3	+0.6	90	18	87	74	23	77	13	77	76	[2]83	14.21	+1.8	27	5,974	n.	23	w.	15	0	11	20	8.2	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[1]29.27	[1]29.78	----	49.1	----	79	30	61	26	7	37	39	44	34	54	0.68	----	8	----	e.	----	----	----	5	13	13	6.5	T.	0.0
Juneau	80	11	50	[1]29.87	[1]29.96	----	46.4	----	72	28	54	32	19	39	33	42	37	75	3.87	----	17	4,360	s.	26	e.	4	2	9	20	7.5	T.	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1]30.05	[1]30.09	----	75.4	+0.6	82	30	80	69	4	71	11	67	62	65	0.33	−1.4	8	7,523	e.	31	e.	1	17	14	0	3.4	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken bihourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, May, 1930*

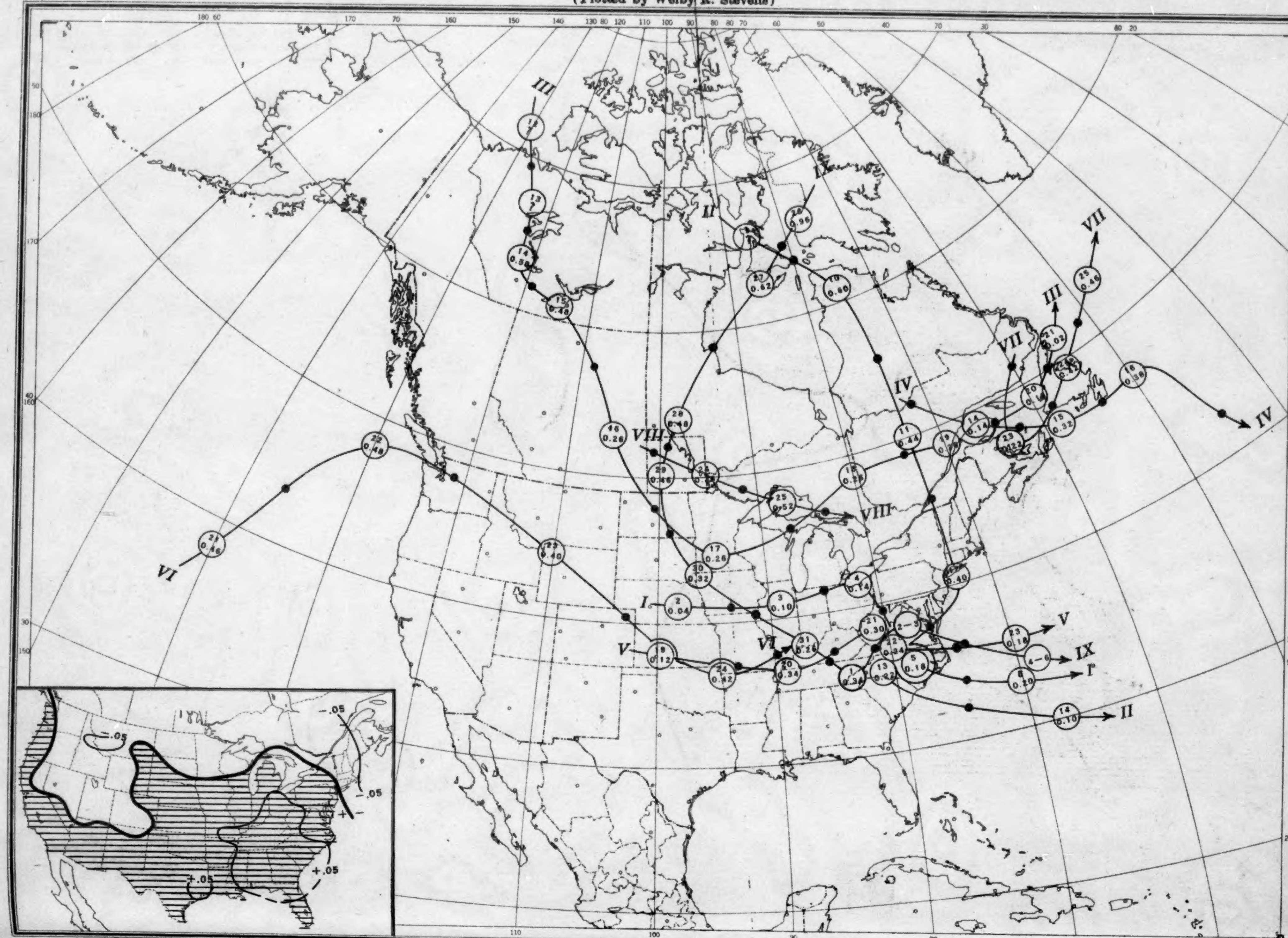
Stations	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	Inches	Inches	Inches	°F.	°F.	°F.	°F.	°F.	°F.	Inches	Inches	Inches
Cape Race, N. F.	90				38.8		46.7	30.9	55	15	6.27		0.0
Sydney, C. B. I.	48	29.85	29.90	−0.07	44.2	−1.0	56.2	32.1	74	30	4.32	+0.55	0.0
Halifax, N. S.	88	29.81	29.92	−.06	48.8	+0.4	58.9	38.8	79	28	4.24	−0.02	T.
Yarmouth, N. S.	65	29.80	29.87	−.11	48.7	+1.1	55.8	41.6	66	34	1.75	−1.82	0.0
Charlottetown, P. E. I.	38	29.81	29.85	−.11	47.9	+1.0	56.3	39.6	71	32	1.95	−0.96	0.0
Chatham, N. B.	28	29.80	29.83	−.12	48.6	+0.1	59.6	37.6	71	28	3.31	+0.10	0.0
Father Point, Que.	20												
Quebec, Que.	296	29.60	29.92	−.02	52.1	+2.2	61.0	43.3	83	32	4.30	+1.22	0.0
Doucet, Que.	1,236				47.2		59.4	35.0	90	19	1.82		1.9
Montreal, Que.	187	29.70	29.90	−.04	56.6	+1.9	65.9	47.3	86	36	4.13	+1.18	0.0
Ottawa, Ont.	236	29.66	29.92	−.02	57.6	+2.7	68.1	47.2	88	32	2.60	+0.01	0.0
Kingston, Ont.	285	29.65	29.96	.00	54.3	+1.4	62.6	46.1	80	36	4.20	+1.52	0.0
Toronto, Ont.	379	29.57	29.97	−.01	57.5	+4.3	67.3	47.7	87	37	2.74	−0.30	0.0
Cochrane, Ont.	930				48.5		60.0	37.0	86	24	2.94		0.3
White River, Ont.	1,244	28.62	29.94	−.01	47.7	+2.0	60.2	35.1	84	18	3.29	+1.34	0.2
London, Ont.	808				57.5		68.9	46.1	86	32	3.60		0.0
Southampton, Ont.	656	29.27	29.99	+.03	53.4	+2.7	63.4	43.4	84	30	3.50	+1.06	0.0
Parry Sound, Ont.	688	29.28	29.98	+.03	53.6	+2.5	63.0	44.3	79	30	2.81	−0.12	0.0
Port Arthur, Ont.	644	29.24	29.95	−.01	49.0	+3.1	58.7	39.3	80	28	3.24	+1.09	0.0
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.10	29.92	−.04	47.4	−1.0	59.0	35.8	88	22	1.64	+0.19	2.7
Le Pas, Man.	860				47.1		57.8	36.5	79	25	3.56		0.8
Qu'Appelle, Sask.	2,115	27.66	29.91	−.03	46.8	−3.0	57.8	35.9	86	20	1.30	−0.35	5.5
Moose Jaw, Sask.	1,759				50.7		64.9	36.5	89	23	0.92		0.4
Swift Current, Sask.	2,392	27.34	29.85	−.07	50.4	−0.3	63.6	37.1	78	22	0.55	−1.21	0.0
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.28	29.84	−.04	44.3	−2.7	54.2	34.5	69	27	2.27	+0.23	1.3
Prince Albert, Sask.	1,450	28.40	29.98	+.03	48.3	+0.7	60.8	35.8	84	26	1.37	+0.11	0.0
Battleford, Sask.	1,592	28.16	29.89	−.03	49.4	−1.6	62.2	36.6	79	24	1.47	−0.15	0.3
Edmonton, Alb.	2,150	27.55	29.82	−.06	48.8	−2.0	59.7	38.0	74	26	1.77	+0.22	7.5
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.73	29.98	−.02	52.0	−0.5	58.5	45.5	68	40	0.53	−0.95	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												
LATE REPORTS, APRIL, 1930													
Doucet, Que.	1,236				29.9		42.5	17.3	62	−4	1.46		7.0
Winnipeg, Man.	760	29.19	30.04	+.02	43.3	+7.4	53.7	32.9	71	17	0.53	−0.52	0.2
Minnedosa, Man.	1,690	28.18	30.03	+.02	41.4	+5.4	53.7	29.2	76	10	0.97	−0.09	T.
Swift Current, Sask.	2,392	27.35	29.88	−.08	47.4	+6.1	61.7	33.1	74	14	1.79	+0.86	0.0
Medicine Hat, Alb.	2,144	27.55	29.80	−.12	50.9	+6.4	63.9	37.9	81	21	1.68	+0.94	0.0
Calgary, Alb.	3,428	26.33	29.90	.00	44.1	+4.5	57.0	31.3	76	22	2.99	+2.35	0.0
Banff, Alb.	4,521	25.29	29.87	−.03	41.5	+6.2	52.3	30.7	63	21	1.78	+0.70	5.6
Edmonton, Alb.	2,150	27.56	29.85	−.04	43.3	+3.4	55.8	30.9	70	16	0.62	−0.26	2.6
Kamloops, B. C.	1,262	28.60	29.89	−.04	53.2	+4.3	64.4	42.1	73	32	0.69	+0.30	0.0
Estevan Point, B. C.	20				46.8		52.7	40.9	58	32	6.60		0.0
Prince Rupert, B. C.	170				43.4		49.8	37.1	64	30	5.56		0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, May, 1930

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, May, 1930. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)



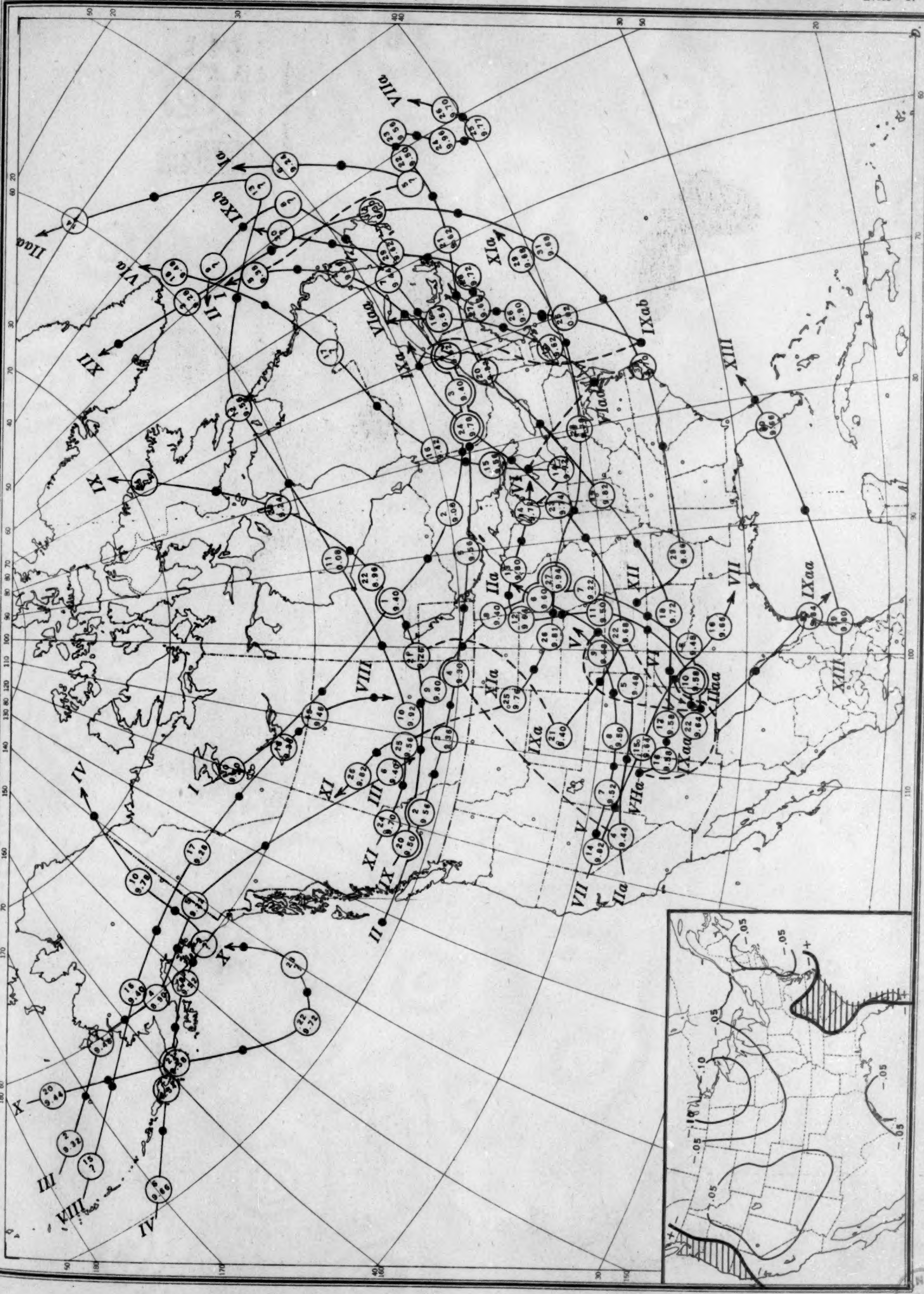
Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, May, 1930. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)

Chart III. Tracks of Centers of Cyclones, May, 1930. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, May, 1930

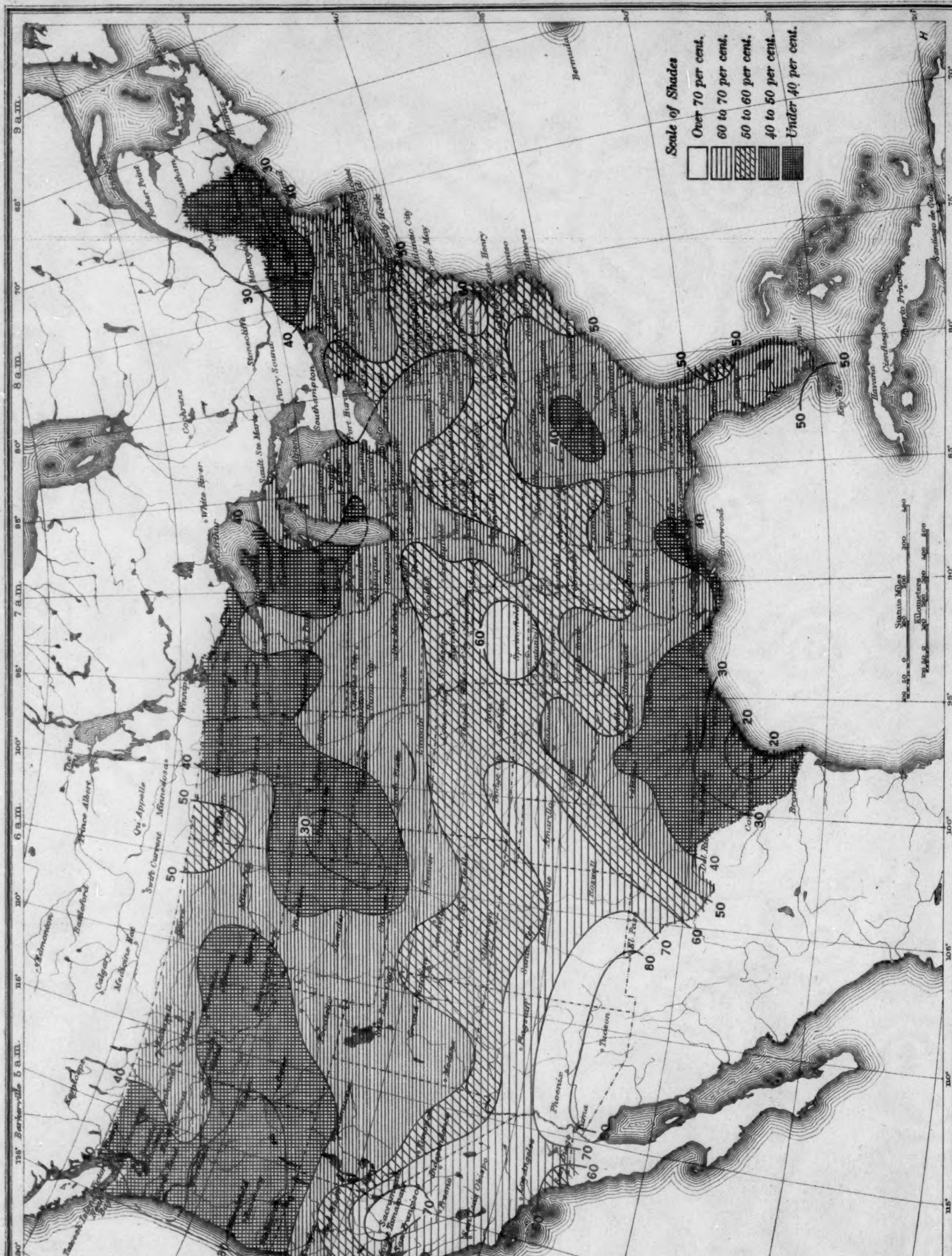


Chart V. Total Precipitation, Inches, May, 1930. (Inset) Departure of Precipitation from Normal

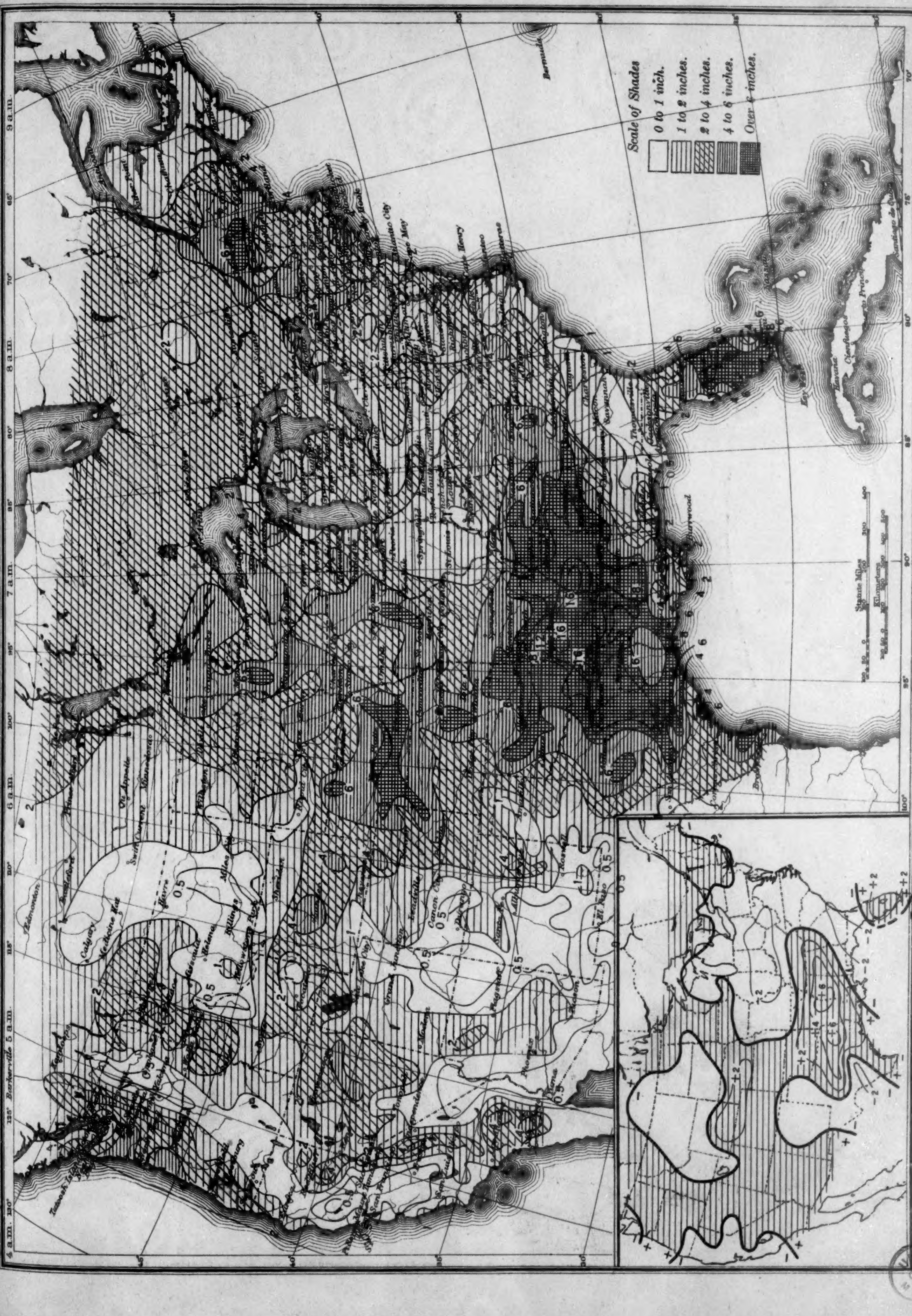


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, May, 1930

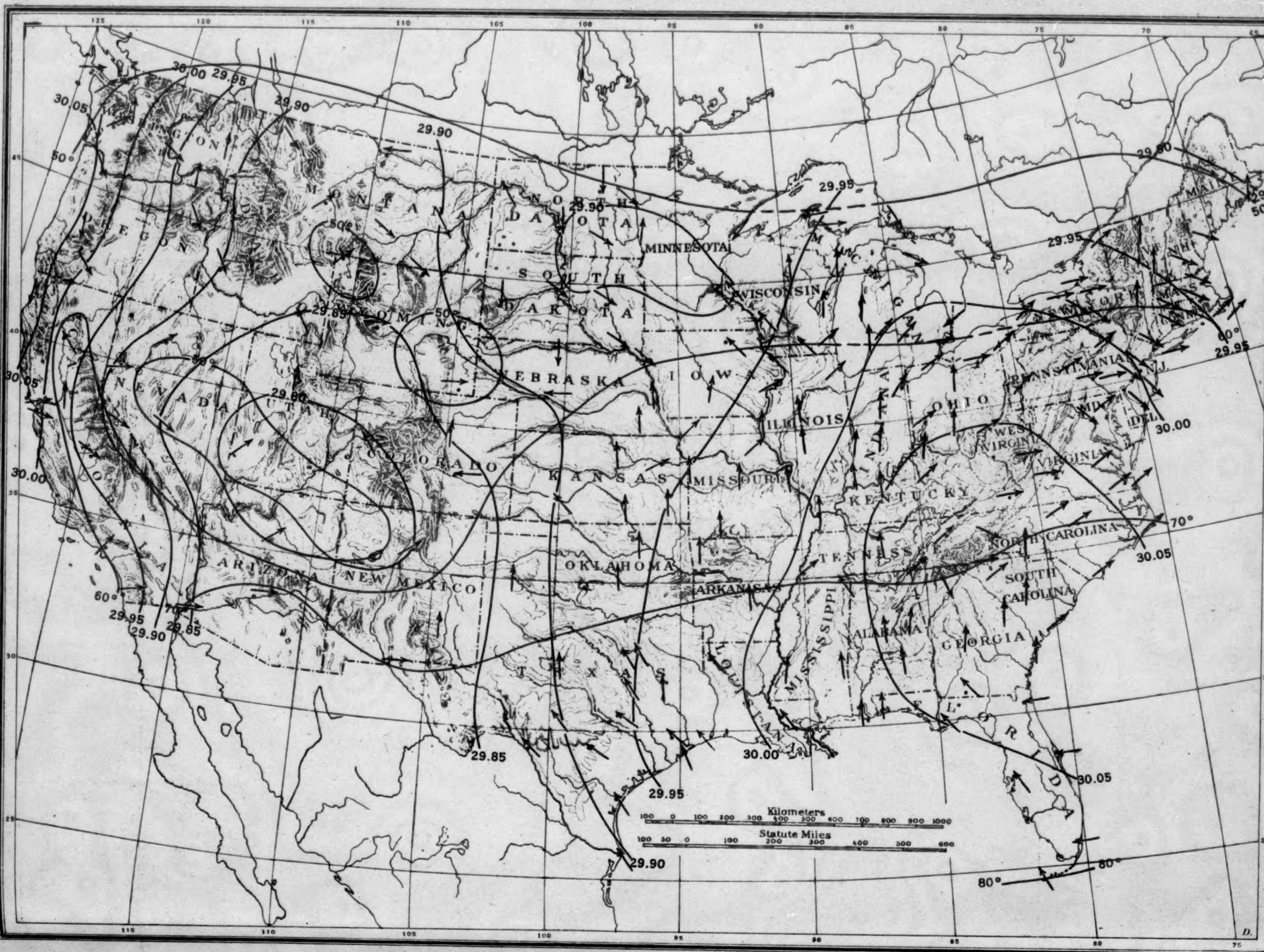


Chart VIII. Weather Map of North Atlantic Ocean, May 1, 1930
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, May 1, 1930
(Plotted by F. A. Young)

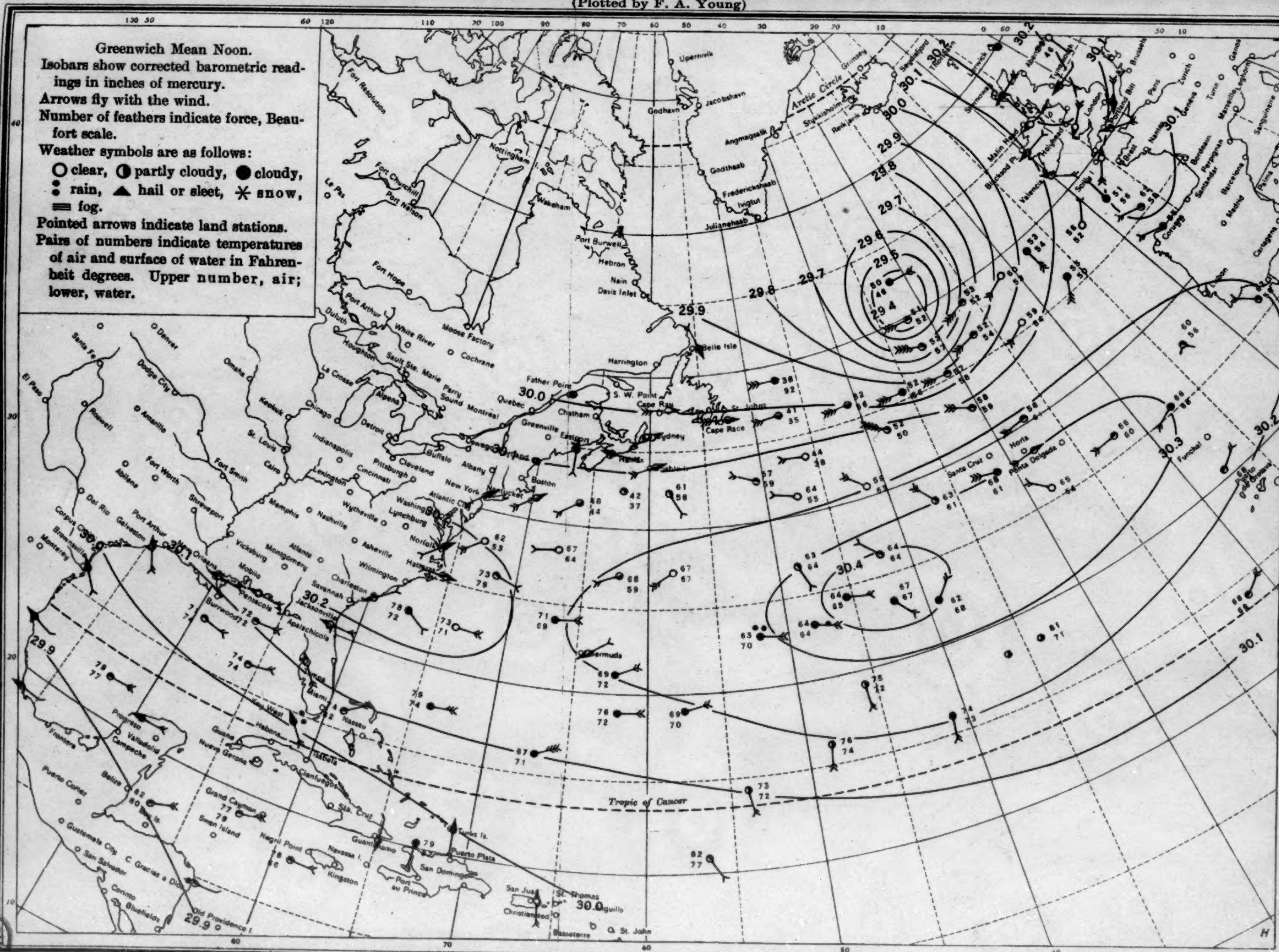


Chart IX. Weather Map of North Atlantic Ocean, May 2, 1930

(Plotted by F. A. Young)

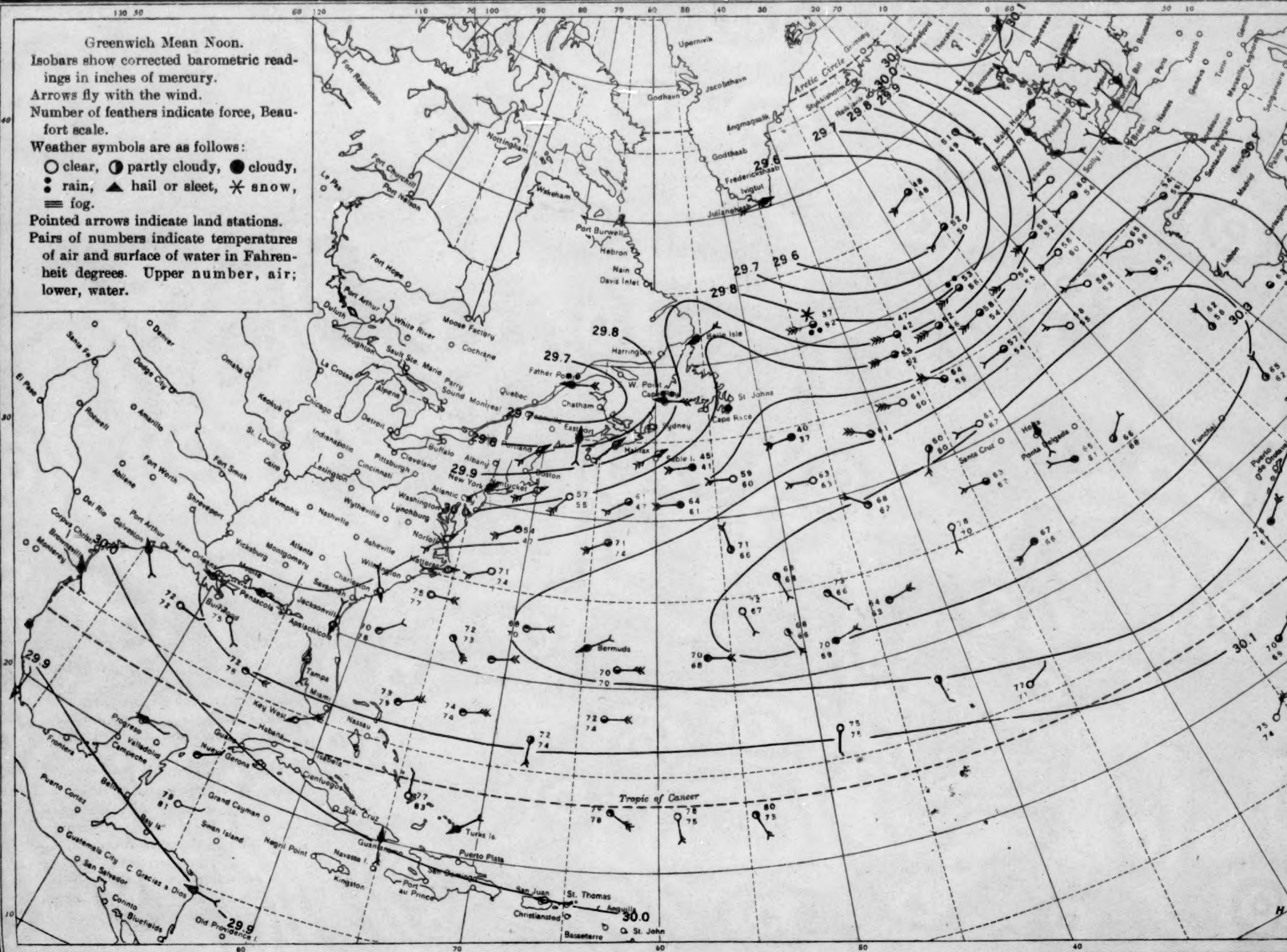


Chart X. Weather Map of North Atlantic Ocean, May 3, 1930
(Plotted by F. A. Young)

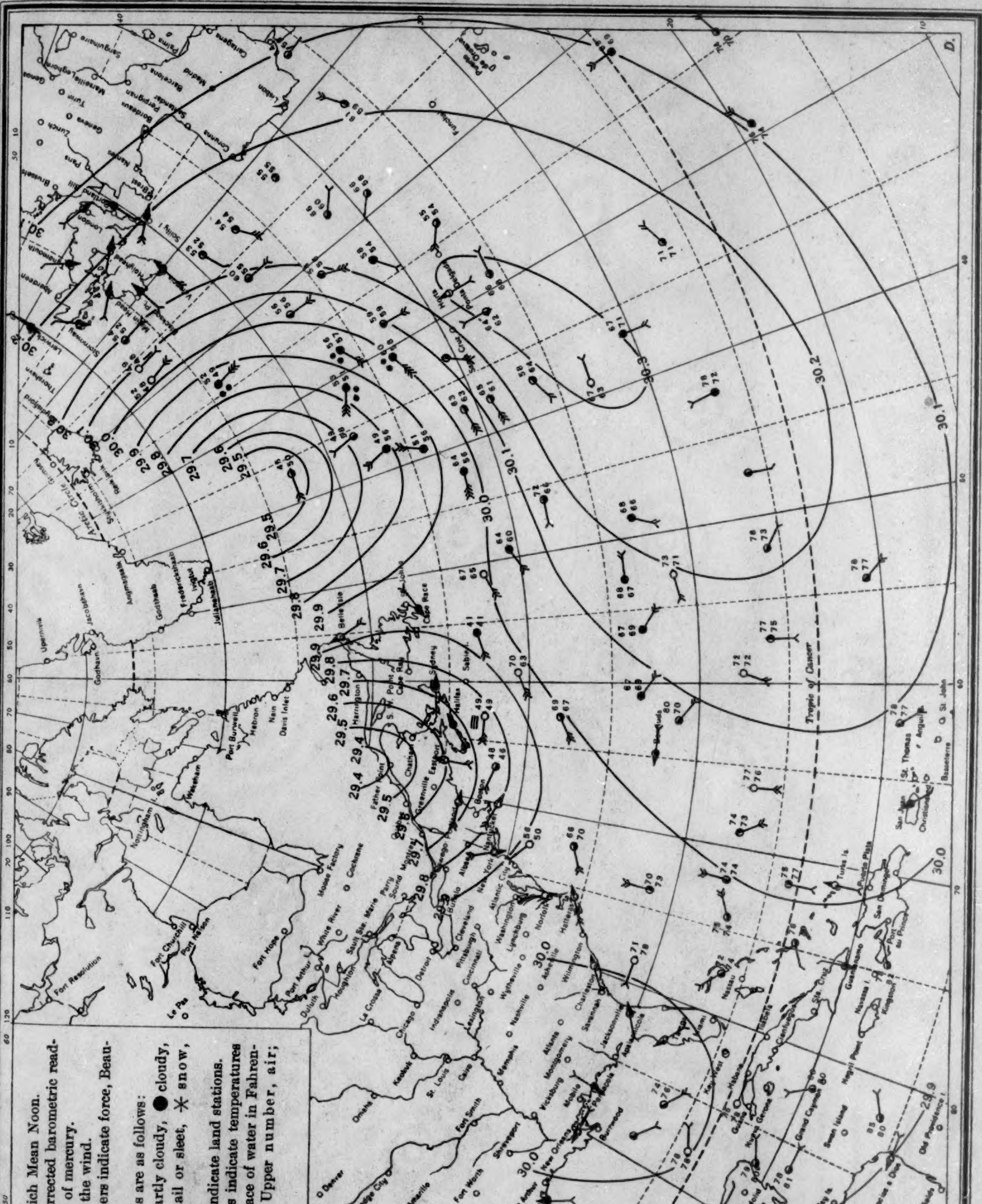


Chart X. Weather Map of North Atlantic Ocean, May 3, 1930
(Plotted by F. A. Young)

Chart XI. Weather Map of North Atlantic Ocean, May 4, 1930
(Plotted by F. A. Young)